

Modeling The Dimensional Stability Of Linen Fabrics

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Abstract— This article relates the dimensional stability of fabrics made from linen. More precisely in this work we find the shrinkage's evolution and shrinkage of linen fabrics after washing and drying. To do this, several articles made of linen are studied in order to have a better appreciation of the behavior of linen fabrics. Knowing that the reference values for the study of dimensional stability are the width defined in centimeters (cm), the initial dimension and the dimension after washing the sample in centimeters and the difference illustrated in percentage. This percentage which reflects the elongation or shrinkage of the fabric is shown by equations which represent the mathematical models of the dimensional stability of the linen fabric. During this study, two types of sample groups are considered: dyed linen fabrics and white linen fabrics. When mathematically modeling dimensional stability, the accuracy of the models are defined by the respective relative and absolute errors.

Keywords— Dimensional Stability, Error, Modelization, Fabric, Linen.

I. INTRODUCTION

Fabrics made from natural fibers are quite complex because the yarns are impacted by several parameters, namely their origin and the related climate. This work is dedicated to the study of the parameters guaranteeing the quality of fabrics made from a linen blend. Dimensional stability of fabrics is the parameter that reflects the ability of fabrics to stretch or shrink after washing and drying.

Before being delivered to the customer, the fabrics must comply with current standards. One of the main standards to respect is dimensional stability because it is the guarantee that after washing and drying, the fabric remains stable. This parameter being respected, the fabric has a lifespan that complies with standards.

The aim of this work is to study the characteristics of dimensional stability on groups of dyed and manufactured white woven fabric composed of linen. To do this, several samples of fabric composed of linen are studied according to the rules and standards

of dimensional stability measurement, then the results obtained in percentage will be represented by mathematical models whose precision is illustrated by the relative errors and absolute errors.

II. DIMENSIONAL STABILITY METHODOLOGY

A. Rule for Sampling and Measuring Fabrics

To have a good appreciation of the measurement of dimensional stability, it is essential to follow the sampling standards. In that case, 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.

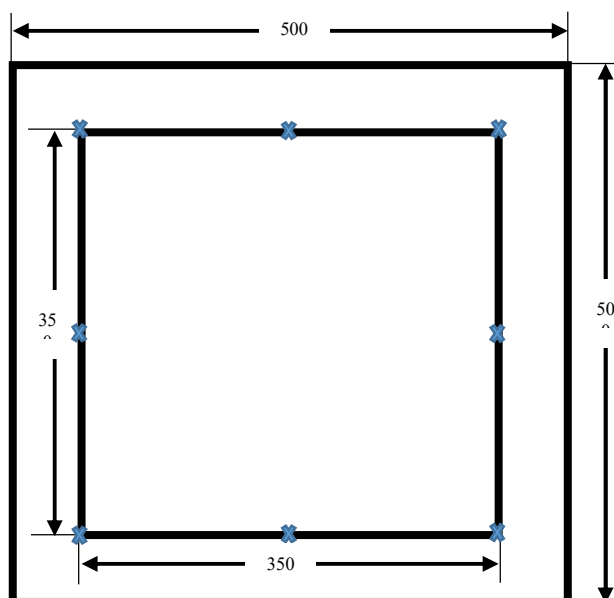


Fig. 1. fabric sampling

B. 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 the following Table 1:

TABLE I. WASH PARAMETER – PROCEDURE 4N

Washing	Temp a [°C]	40±3
	<i>Liquor level b c [mm]</i>	<i>100</i>
	<i>Wash time d [min]</i>	<i>15</i>
	<i>Cool down f</i>	<i>No</i>
Rinse 1	<i>Liquor level b c [mm]</i>	<i>130</i>
	<i>Rinse time d g [min]</i>	<i>3</i>
Rinse 2	<i>Liquor level b c [mm]</i>	<i>130</i>
	<i>Rinse time d g [min]</i>	<i>3</i>
	<i>Spin time d [min]</i>	<i>-</i>
Rinse 3	<i>Liquor level b c [mm]</i>	<i>130</i>
	<i>Rinse time d g [min]</i>	<i>2</i>
	<i>Spin time d [min]</i>	<i>-</i>
Rinse 4	<i>Liquor level b c [mm]</i>	<i>130</i>
	<i>Rinse time e g [min]</i>	<i>2</i>
	<i>Spin time d [min]</i>	<i>5</i>

- 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.

C. 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:

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

- 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 mathematical models of the dimensional stability of fabrics composed of linen. To do this, several samples were studied and divided into two very distinct groups, namely dyed woven fabrics and white fabrics.

The fabric samples taken from the group of dyed woven fabrics are formed by 3 fabrics variants in which characteristics are illustrated in Table I:

TABLE I. CHARACTERISTICS AND VARIANTS OF DYED WOVEN FABRICS

<i>Variant</i>	<i>Ends/cm</i>	<i>Picks/cm</i>	<i>Warp</i>	<i>Weft</i>	<i>Weight/m²</i>	<i>Composition</i>	<i>width</i>
<i>VarT1</i>	21	20	34C	34C	125	78 % coton 22 % linen	154
<i>VarT2</i>	22	20	34C	34C	120	55 % coton 45 % linen	158
<i>VarT3</i>	23	18	34C	34C	115	55 % coton 45 % linen	157

For fabrics woven in white we also considered 3 variants but with several samples per variant. The variants considered as well as their characteristics are illustrated in Table II:

TABLE II. FEATURE AND VARIANT OF WHITE WOVEN FABRIC

<i>Variant</i>	<i>Ends/cm</i>	<i>Picks/cm</i>	<i>Warp</i>	<i>Weft</i>	<i>Weight/m²</i>	<i>Composition</i>	<i>width</i>
<i>VarB1</i>	25	20	34C	34C	125	77 % coton 23 % linen	144
<i>VarB2</i>	25	20	34C	34C	130	55 % coton 45 % linen	149
<i>VarB3</i>	24	18	34C	34C	115	55 % coton 45 % linen	146

The yarn characteristics constituting the fabric are illustrated in Table III:

TABLE III. OVERALL CHARACTERISTIC OF THE CONSTITUTING YARNS OF FABRICS

<i>Settings</i>	<i>VarT1</i>	<i>VarT2</i>	<i>VarT3</i>	<i>VarB1</i>	<i>VarB2</i>	<i>VarB3</i>
<i>Metric number</i>	34	34	34	34	34	34
<i>Origin</i>	<i>Pakistan</i>	<i>China</i>	<i>China</i>	<i>China</i>	<i>Pakistan</i>	<i>China</i>
<i>Coefficient of variation</i>	1,95	2,16	2,08	1,99	2,26	1,95
<i>Finesse</i>	425	328	1039	5238	994	425
<i>Size</i>	750	1557	1944	618	2380	750
<i>NEPS</i>	1883	1768	2196	2715	3810	1833
<i>Imperfection</i>	3058	3653	5179	8571	7184	3008
<i>Hair index</i>	4,82	5,8	5,07	5,15	6,18	4,82
<i>RKM</i>	16,12	12,74	14,81	16,95	14,76	12,22

<i>Elongation</i>	<i>5,98</i>	<i>4,42</i>	<i>4,85</i>	<i>4,76</i>	<i>4,73</i>	<i>3,51</i>
<i>Spinning system</i>	<i>Card</i>	<i>Card</i>	<i>Card</i>	<i>Card</i>	<i>Card</i>	<i>Card</i>

IV. PRESENTATION OF THE RESULTS

During our study the aim is to model the dimensional stability of linen-based fabrics. To do this, we considered two types of linen fabric, namely dyed woven linen fabric and white woven linen fabrics. For each type we studied several batches of fabric which we distinguished by 3 variants named Var1 2, 3. Consequently, the results presented in this work show the mathematical models of the dimensional stability of the fabrics for each variant and for the fabrics based on linen in general which helps us understand the dynamic behavior of linen-based fabrics after washing and drying.

A. Model of dimensional stability for dyed woven fabrics

The behaviors of the dimensional stability of the dyed woven fabrics studied during our work are presented by the mathematical models below:

1) Case of VarT1 samples:

The mathematical models detailed in this section are the result of monitoring 32 articles of the same type in the VarT1 category.

- Warp study

When studying dimensional stability, the measurement is always done in warp and weft. After analysis of the results and the appropriate calculations carried out, the mathematical model of the warp dimensional stability of the fabric composed of linen of group VarT1 is given by equation 2:

$$DS_{T1C}(x) = 2,41 * \sin(0,02 * x + 121) \quad (2)$$

x : represents the width of the fabric in [cm]

$DS_{T1C}(x)$: represents the warp dimensional stability of the VarT1 fabric in [%]

The precision of this model is given by the errors, namely the relative error and the absolute error:

- Absolute error : $\Delta DS = 0,06$ [%]
- Relative error : $\frac{\Delta DS}{DS} = 2,77\%$

The curve illustrating the evolution of dimensional stability given by equation 2 is represented by Figure 2:

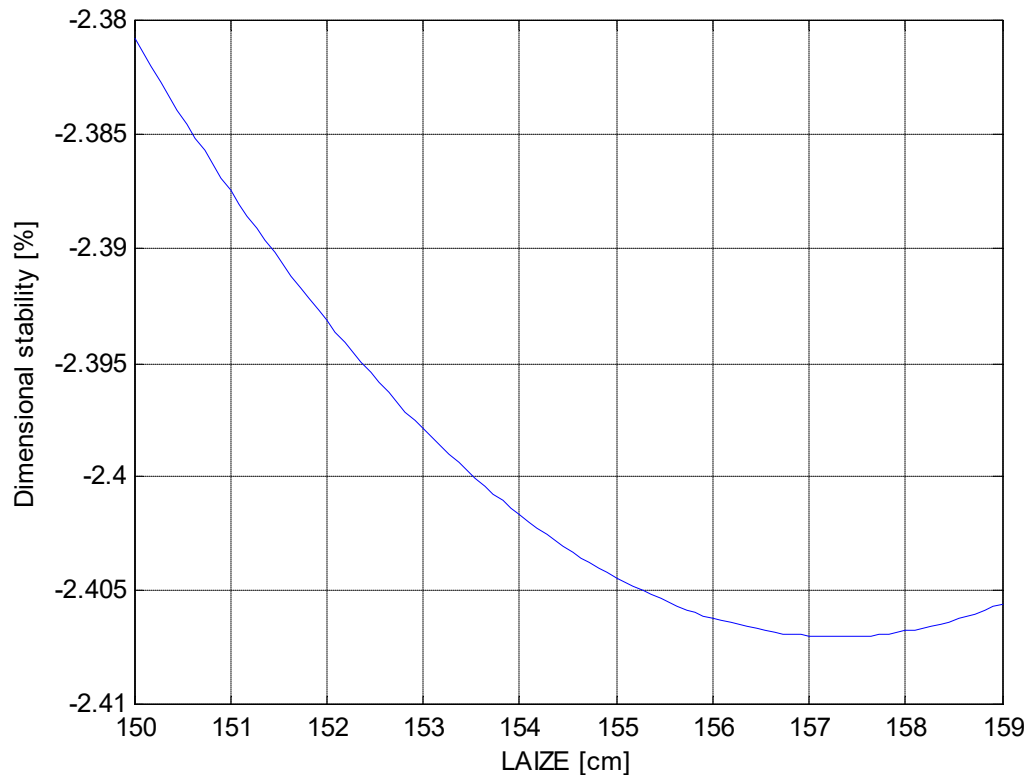


Fig. 2. Representative curve of equation 2

On this curve we see that the more the width increases, the more the fabric tends to shrink after washing but the shrinkage limit value is -2.41%. The limit of the value of the warp dimensional stability of the VarT1 type fabric corresponds to the fabric with a width of 157 cm. The respective maximum and minimum values of dimensional stability are -2.38% and -2.41% with the model and during measurements, these values are respectively 0 and -5% which is justified by the precision errors of the equation.

- Weft study

Equation 3 illustrates the mathematical model of the weft dimensional stability of the fabric composed of linen of group VarT1:

$$DS_{T1T}(x) = -2,08 + 0,87 \cos(1,34x) - 0,21\sin(1,34x) \quad (3)$$

x : represents the width of the fabric in [cm]

$DS_{T1T}(x)$: represents the weft dimensional stability of the VarT1 fabric in [%]

The precision of this model is given by the errors namely the relative error and the absolute error:

- Absolute error : $\Delta DS = 0.11$ [%]
- Relative error : $\frac{\Delta DS}{DS} = 3.72\%$

The curve representative of the evolution of dimensional stability given by equation 3 is shown in Figure 3:

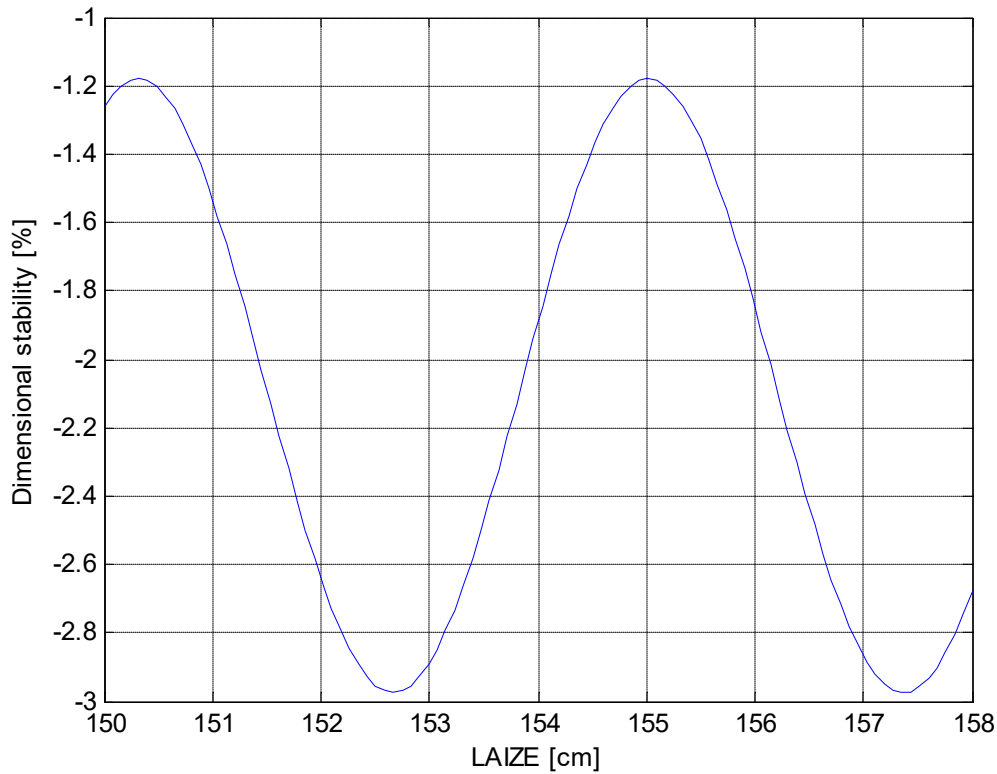


Fig. 3. Representative curve of equation 3

On this curve we see that the average value of the dimensional stability in weft of the VarT1 type fabric is -2%, therefore we can say that the fabric meets the quality standards. The extreme values are -1.2% and -2.9% respectively. During measurements, these values are respectively -0.5% and -3.5% which is justified by the precision errors of the equation.

2) Case of VarT2 samples:

The mathematical models detailed in this section are the result of monitoring 37 articles of the same type in the VarT2 category.

• Warp study

The analyzes and study of the 37 samples of VarT2 type fabric articles allows us to determine the behavior of the dimensional stability of this type of fabric. Equation 4 represents the mathematical model of the warp dimensional stability of the fabric composed of linen of group VarT2:

$$DS_{T2C}(x) = -4 + 0.1 \sin(2.8x^2) + 0.24e^{-(0.35x)^2} \quad (4)$$

x : represents the width of the fabric in [cm]

$DS_{T2C}(x)$: represents the warp dimensional stability of the VarT2 fabric in [%]

The precision of this model is given by the errors namely the relative error and the absolute error:

- Absolute error : $\Delta DS = 0.48$ [%]
- Relative error : $\frac{\Delta DS}{DS} = 10.67\%$

The curve representative of the evolution of dimensional stability in warp given by equation 4 is illustrated in Figure 4:

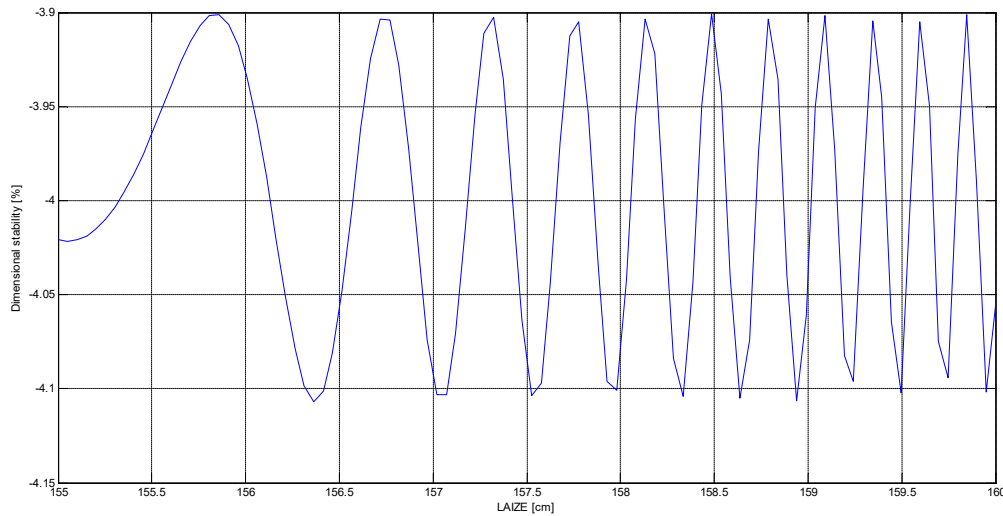


Fig. 4. Representative curve of equation 4

On this curve we see that the average value of the warp dimensional stability of the VarT2 type fabric is -4%, we can say that the fabric is stable because the standard is respected. Despite the difference in sample widths, the extreme values of dimensional stability remain constant. The values oscillate between -3.9% and -4.1% and during measurements, these values are respectively -1% and -5% which is justified by the very small precision errors of the equation.

- Weft study

Equation 5 demonstrates the mathematical model of the dimensional stability in weft of the fabric composed of linen of group VarT2:

$$DS_{T2T}(x) = -4,15 + 0,6 \cos(1,55x) - 0,28\sin(1,55x) \quad (5)$$

x : represents the width of the fabric in [cm]

$DS_{T2T}(x)$: represents the weft dimensional stability of the VarT2 fabric in [%]

The precision of this model is given by the errors namely the relative error and the absolute error:

- Absolute error : $\Delta DS = 0,62$ [%]
- Relative error : $\frac{\Delta DS}{DS} = 17,58\%$

The representative curve of the evolution of dimensional stability in weft given by equation 5 is shown in Figure 5:

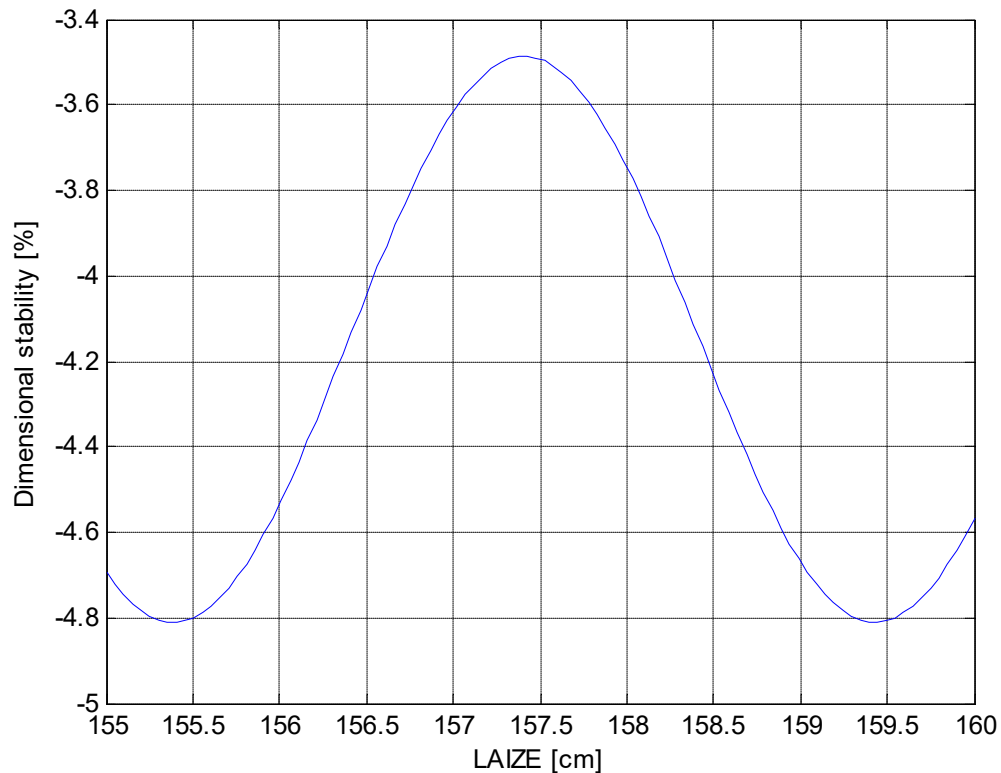


Fig. 5. Representative curve of equation 5

In this figure we see that the fabric tends to shrink after washing, which is a sign of quality, because the dimensional stability values are negative. The average value of the weft dimensional stability of the VarT2 type fabric is -4.2%. The extremum values are -3.5% and -4.8% and during measurements, these values are respectively -1% and -5.5% which is illustrated by the fairly small precision errors of the equation.

3) Case of VarT3 samples:

The mathematical models detailed in this section are the result of monitoring 51 articles of the same type in the VarT3 category.

- Warp study

Monitoring the 51 articles of VarT3 type fabric allows us to determine the behavior of the dimensional stability of this type of fabric. Equation 6 represents the mathematical model of the warp dimensional stability of the fabric composed of linen of group VarT3:

$$DS_{T3C}(x) = -8,7 \exp \left(-\left(\frac{x - 159,7}{11,95} \right)^2 \right) \quad (6)$$

x : represents the width of the fabric in [cm]

$DS_{T3C}(x)$: represents the warp dimensional stability of the VarT3 fabric in [%]

The precision of this model is given by the errors namely the relative error and the absolute error:

- Absolute error : $\Delta DS = 0.44 \text{ [\%]}$
- Relative error : $\frac{\Delta DS}{DS} = 14.5\%$

Figure 6 represents the shape of the curve of the evolution of dimensional stability in warp given by equation 6:

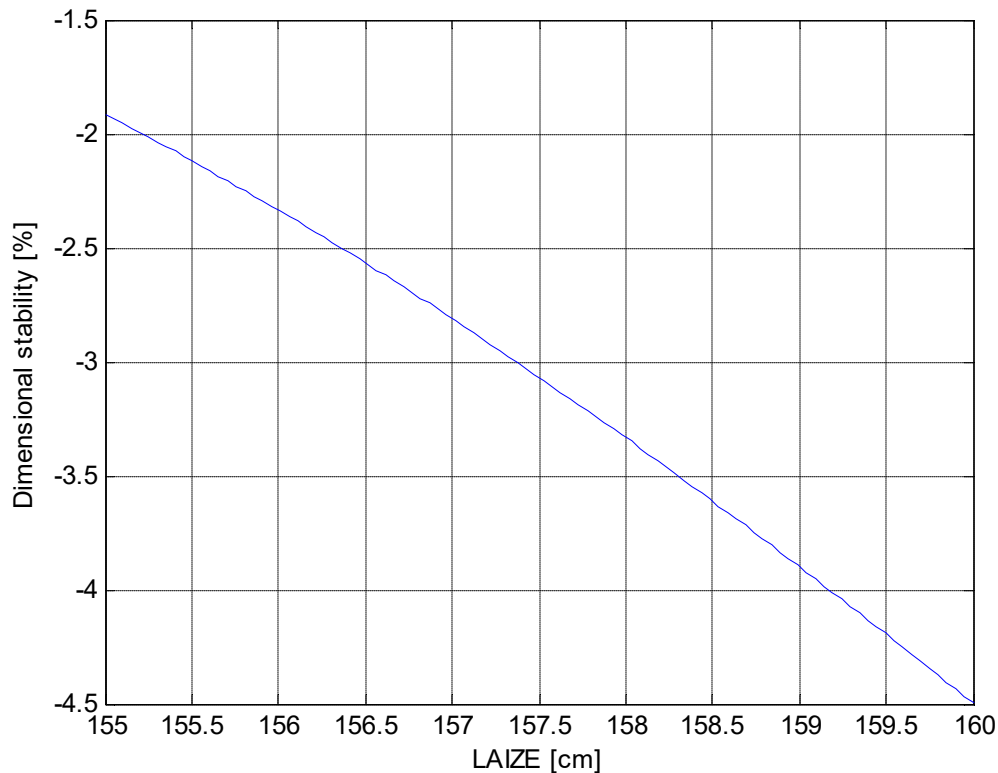


Fig. 6. Representative curve of equation 6

We note the value of that the more the width of the fabric increases, the more the fabric tends to shrink after washing. The average value of warp dimensional stability of VarT3 type fabric varies from -2% to -4.5 for fabrics with a width between 155 cm and 159 cm. During measurements, these values are respectively -1% and -5% which is justified by the fairly small precision errors of the equation.

- Weft study

Equation 7 represents the mathematical model of the dimensional stability in weft of the fabric composed of linen of group VarT3:

$$DS_{T3T}(x) = 30,58 * \sin(9,6 * 10^{-2}x + 121) \quad (7)$$

x : represents the width of the fabric in [cm]

$DS_{T3T}(x)$: represents the warp dimensional stability of the VarT3 fabric in [%]

The precision of this model is given by the errors namely the relative error and the absolute error:

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

– Relative error : $\frac{\Delta DS}{DS} = 5,49\%$

Figure 7 illustrates the shape of the curve of the evolution of dimensional stability in warp given by equation 7:

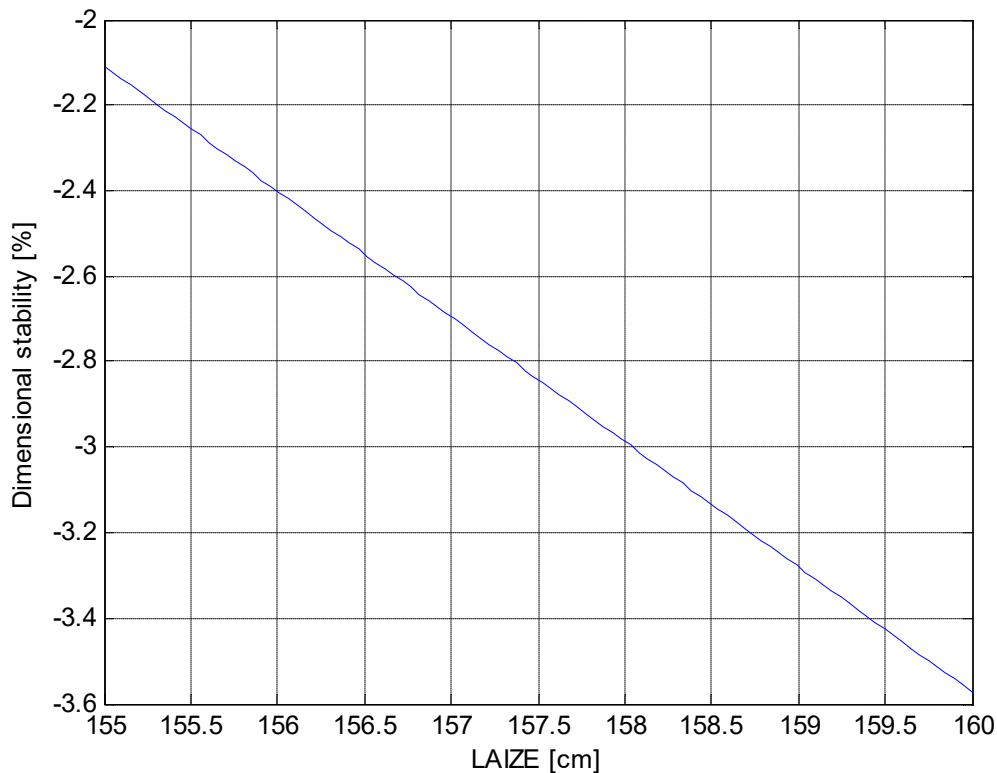


Fig. 7. Representative curve of equation 7

The curve illustrating the evolution of dimensional stability in weft presented in Figure 7 is quite similar to that of the warp presented in Figure 6. However, the slope values are different for the two curves. The respective values of the maximums and minimums are -2.1% and -3.3% because the samples considered have a width of between 155 cm and 159 cm. During measurements, these values are respectively -1% and -4.5% which is justified by the very small precision errors of the equation.

4) Model of the dimensional stability of linen-dyed woven fabrics:

- Warp model

We can give a general equation illustrating the evolution of the warp dimensional stability of linen dyed woven fabrics by taking into consideration the 3 types of dyed woven fabric. This mathematical model is given by equation 8 below:

$$DS_{TC}(x) = -2,7 - 0,45 \sin(2,93 x^2) + 0,85 e^{-(0,68x)^2} \quad (8)$$

x : represents the width of the fabric in [cm]

$DS_{TC}(x)$: represents the warp dimensional stability of the dyed woven fabric in [%]

Equation (8) representing the model of the dimensional stability of the precision-dyed woven fabric whose values are given by the errors, namely:

- Absolute error : $\Delta DS = 0.07$ [%]
- Relative error : $\frac{\Delta DS}{DS} = 2.5\%$

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

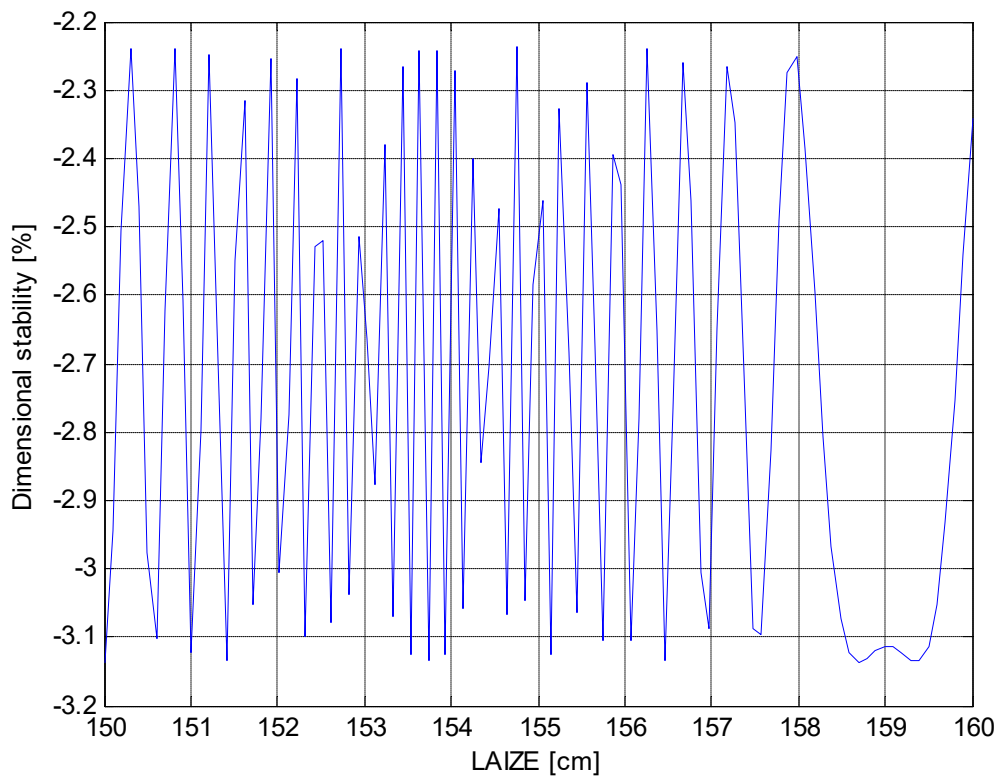


Fig. 8. Representative curve of equation 8

We note the representative curve, the warp dimensional stability of linen dyed fabrics oscillates around the average value of -2.7%. We notice quite vaguely the 3 types of fabrics (VarT1, VarT2, VarT3) to consider when sampling during the study. The respective maximum and minimum values are -2.2% and -3.2% during modeling, during the experiment these values are -1 and -3%. Consequently, we have a very precise equation which is justified by the value of the errors.

- Weft model

With the 3 types of dyed woven fabric studied, namely VarT1, VarT2 and VarT3, we can give a general equation illustrating the evolution of the dimensional stability in the weft of linen-dyed woven fabrics. This mathematical model is given by the following equation 9:

$$DS_{TF}(x) = -5,16 - 0,74 \cos(0,23x) - 2,9 \sin(0,23x) \quad (9)$$

x : represents the width of the fabric in [cm]

$DS_{TT}(x)$: represents the weft dimensional stability of the dyed woven fabric in [%]

The accuracy of equation (9) representing the weft dimensional stability model of the dyed woven fabric is given by the errors, namely:

- Absolute error : $\Delta DS = 0.17$ [%]
- Relative error : $\frac{\Delta DS}{DS} = 7.8\%$

The representative curve of equation 9 is given by figure 9:

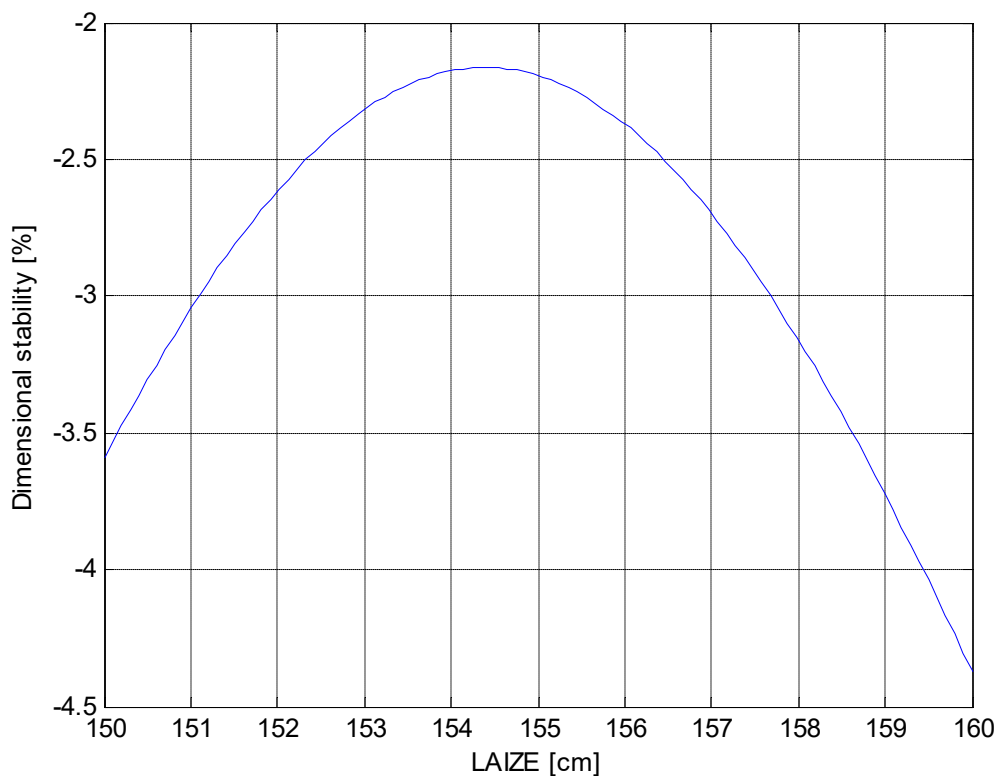


Fig. 9. Representative curve of equation 9

In Figure 9, we note that the value of the weft dimensional stability of the dyed woven fabric varies between -2.2% and -4.3%. The minimum shrinkage value is reached for fabrics with a width between 154 cm and 155 cm. For fabrics with a width between 150 cm and 154 cm, the more the width increases, the more stable the fabric. For fabrics with a width greater than 155 cm, the fabric tends to shrink more and more but the dimensional stability remains within standards. The model presented in equation 9 has a precision error satisfying.

B. Dimensional Stability Model for White Woven Linen Fabrics

The evolution of the dimensional stability of white woven fabrics studied during our work are shown by the mathematical models below:

1) Case of VarB1 samples:

The mathematical models presented in this section were obtained by monitoring and studying 47 articles of the same type in the VarB1 category.

- Warp study

The mathematical model of the warp dimensional stability of the fabric composed of linen of group VarB1 is given by equation 10:

$$DS_{B1C}(x) = -0,71 + 0,24 \sin(1,53x^2) + 0,46e^{-(0,45x)^2} \quad (10)$$

x : represents the width of the fabric in [cm]

$DS_{B1C}(x)$: represents the warp dimensional stability of the VarB1 fabric in [%]

The precision of this model is given by the errors namely the relative error and the absolute error:

- Absolute error : $\Delta DS = 0,1$ [%]
- Relative error : $\frac{\Delta DS}{DS} = 14,59\%$

The curve representative of the evolution of dimensional stability in warp given by equation 10 is illustrated by figure 10:

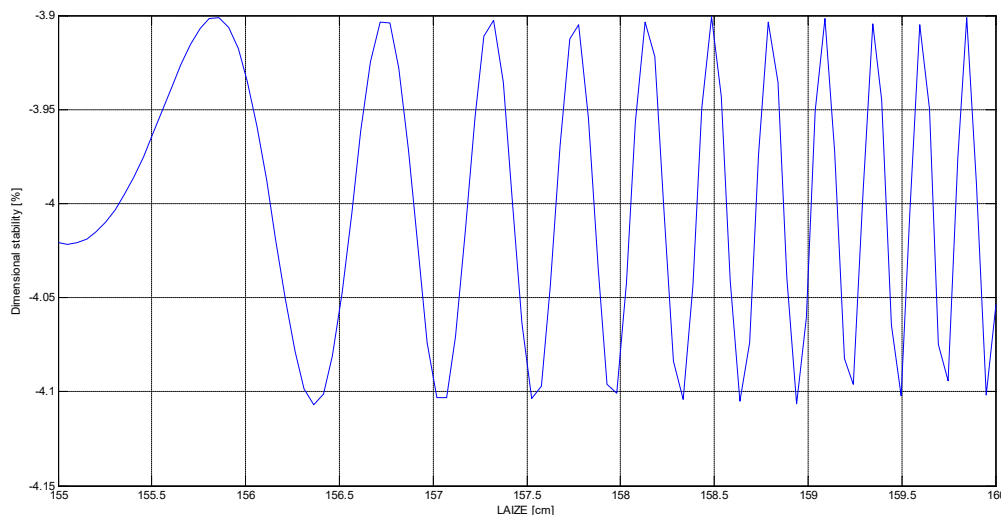


Fig. 10. Representative curve of equation 10

On this curve we see that the average value of the warp dimensional stability of the VarB1 type fabric is -4%, we can say that the fabric is stable because the standard is respected. The extrema of the dimensional stability values as well as the oscillation period are constant. The extreme values are -3.9% and -4.1% respectively. Therefore we can say that the fabrics have similar behaviors and the very small precision errors of the equation are justified.

- Weft study

Equation 11 illustrates the mathematical model of the weft dimensional stability of the fabric composed of linen of group VarB1:

$$DS_{B1F}(x) = -3,9 + 0,35 \sin(0,037x^2) + 0,15e^{-(0,22x)^2} \quad (11)$$

x : represents the width of the fabric in [cm]

$DS_{B1T}(x)$: represents the weft dimensional stability of the VarB1 fabric in [%]

The precision of this model is given by the errors namely the relative error and the absolute error:

- Absolute error : $\Delta DS = 0.4$ [%]
- Relative error : $\frac{\Delta DS}{DS} = 10.14\%$

The representative curve of the evolution of dimensional stability in weft given by equation 11 is illustrated in Figure 11:

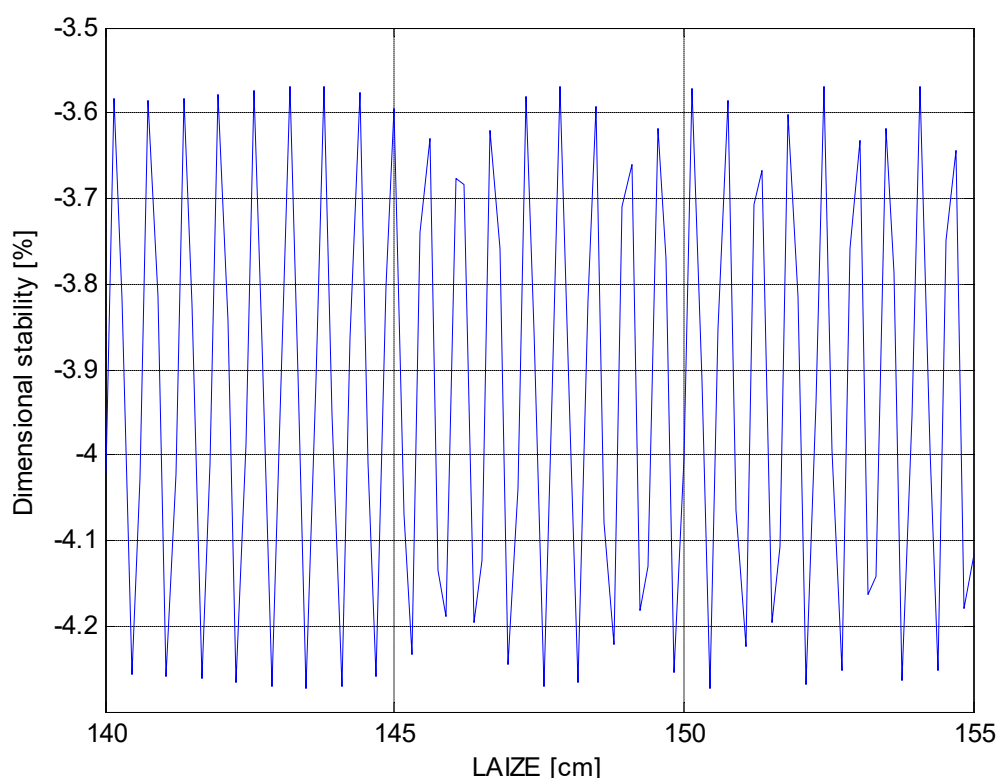


Fig. 11. Representative curve of equation 11

Thus, we see on this curve that the average value of the weft dimensional stability of the VarB1 type fabric is -3.9%, therefore we can say that the fabric meets the quality standards. The extreme values are quite similar but we note that for the same type of fabric, there are 3 very distinct groups. However, only the oscillation periods are different for the 3 groups but the extrema are around -3.6% and -4.2% respectively. During measurements, these values are respectively -2.5% and -4.5% which is justified by the precision errors of the equation.

2) Case of VarB2 samples:

The mathematical models presented in this section were obtained by monitoring and studying 7 articles of the same type in the VarB1 category. Knowing that the production of the fabric is limited by financial means, hence the scarcity of samples obtained for the type of fabric in this group.

- Warp study

The mathematical model of the warp dimensional stability of the fabric composed of linen of group VarB2 is given by equation 12:

$$DS_{B2C}(x) = 2,58 * \sin(0,4 * x - 5,2) \quad (12)$$

x : represents the width of the fabric in [cm]

$DS_{B2C}(x)$: represents the warp dimensional stability of the VarB2 fabric in [%]

The precision of this model is given by the errors namely the relative error and the absolute error:

– Absolute error : $\Delta DS = 0,12$ [%]

– Relative error : $\frac{\Delta DS}{DS} = 8,1\%$

The representative curve of the evolution of dimensional stability in weft given by equation 12 is illustrated by figure 12:

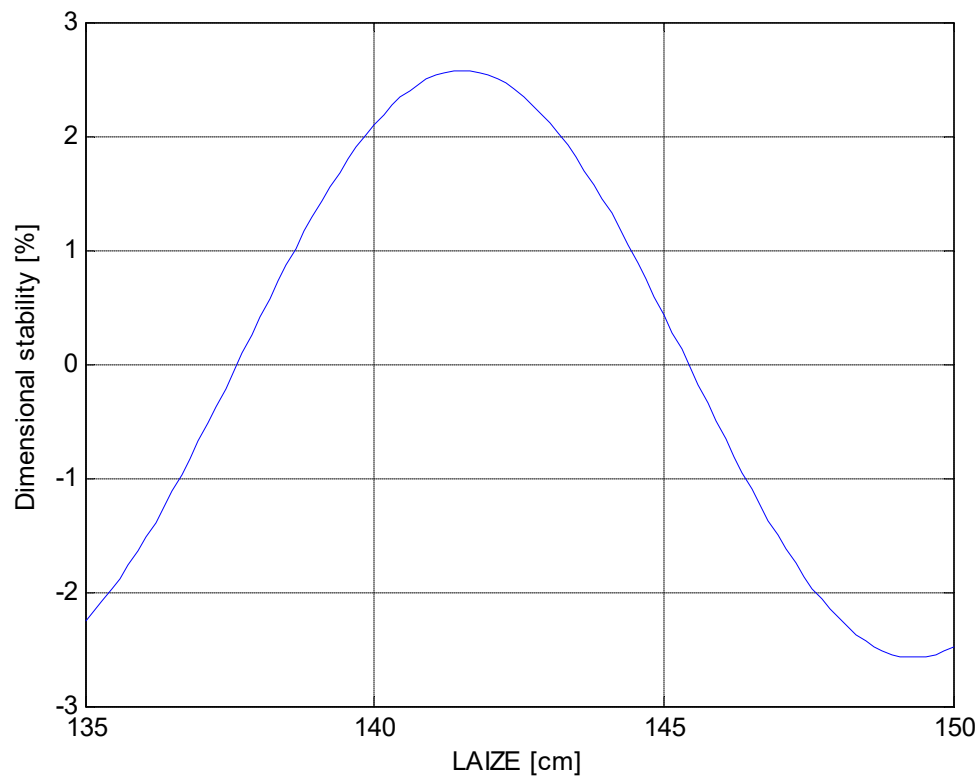


Fig. 12. Representative curve of equation 12

Despite the rarity of the samples studied, we were able to establish models for different types of fabric from the same VarB family. The model illustrated in Figure 12 offers a precision defined by the relative errors of 8%. Dimensional stability varies between -2 and 2.5. The fabric is stable even if fabrics between widths of 140 cm to 145 cm tend to widen after washing.

- Weft study

Equation 13 represents the mathematical model of the dimensional stability in weft of the fabric composed of linen of group VarB2:

$$DS_{B2T}(x) = 70,73 * \sin(3 * 10^{-2}x + 49,74) \quad (13)$$

x : represents the width of the fabric in [cm]

$DS_{B2T}(x)$: represents the weft dimensional stability of the VarB2 fabric in [%]

The precision of this model is given by the errors namely the relative error and the absolute error:

- Absolute error : $\Delta DS = 0,2$ [%]
- Relative error : $\frac{\Delta DS}{DS} = 5,29\%$

The representative curve of the evolution of dimensional stability in weft given by equation 13 is illustrated by figure 13:

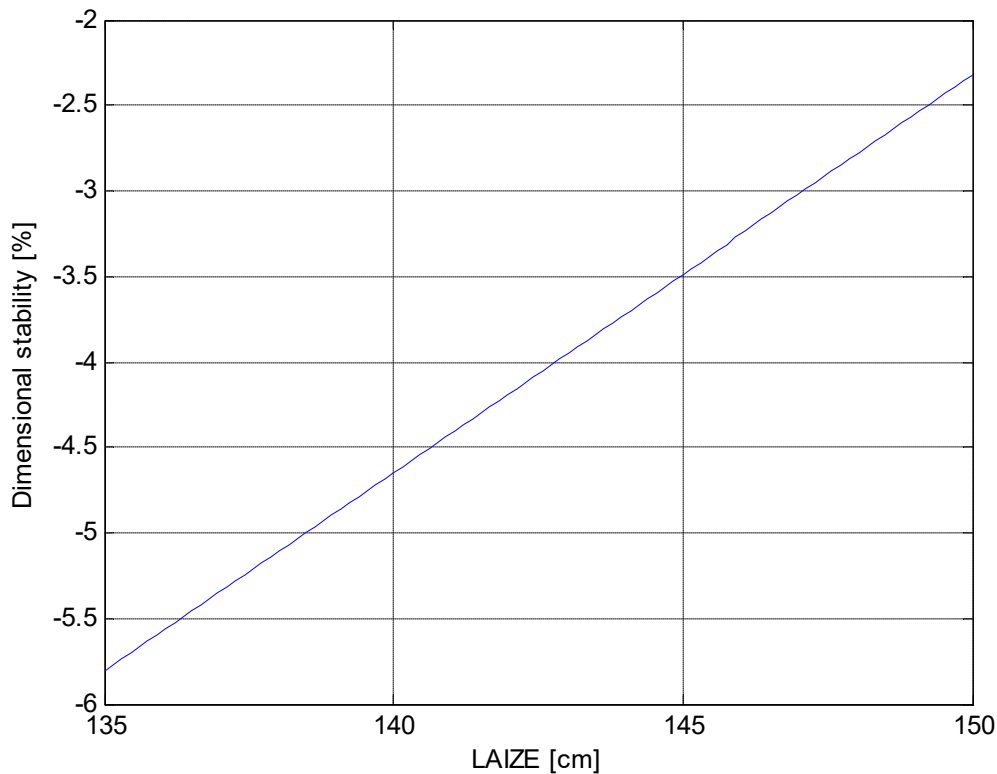


Fig. 13. Representative curve of equation 13

Therefore, we see that the average value of dimensional stability gradually changes with the width of the fabric on this curve. The respective minimum and maximum width of the samples considered during our work being 139 cm and 148 cm, we can say that the fabric is stable because the dimensional stability values vary between -5% and -2.5% and during the measurements, these values are respectively -1.5% and -6% which is justified by the very small precision errors of the equation.

3) Case of VarB3 samples:

The mathematical models presented in this section were obtained by monitoring and studying 19 articles of the same type in the VarB3 category.

- Warp study

The mathematical model of the warp dimensional stability of the fabric composed of linen of group VarB3 is given by equation 14:

$$DS_{B3C}(x) = 2,14 * \sin(0,7x + 53,04) \quad (14)$$

x : represents the width of the fabric in [cm]

$DS_{B3C}(x)$: represents the warp dimensional stability of the VarB3 fabric in [%]

The precision of this model is given by the errors namely the relative error and the absolute error:

- Absolute error : $\Delta DS = 0.07$ [%]
- Relative error : $\frac{\Delta DS}{DS} = 3.82\%$

The curve representative of the evolution of dimensional stability in warp given by equation 14 is illustrated by figure 14:

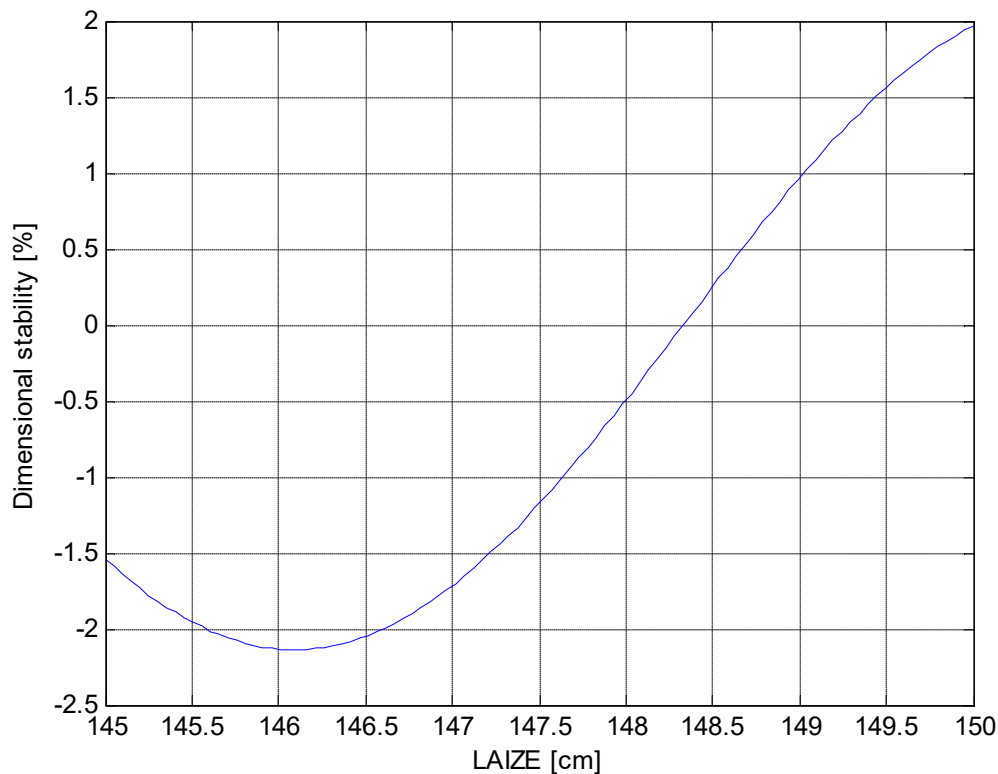


Fig. 14. Representative curve of equation 14

In this figure we notice that fabric with widths less than 148 cm tends to shrink after washing but fabrics with widths greater than 148 cm tend to elongate but remain well below the limit. The extreme values of the warp dimensional stability of the

VarB3 type fabric are -2.10% and -2% and during measurements, these values are respectively 0 and -3% which is justified by the precision errors of the model on equation 14.

- Weft study

The mathematical model of the dimensional stability in weft of the fabric composed of linen of group VarB3 is given by equation 15:

$$DS_{\text{weft}}(x) = -4,18 - 0,23 \sin(2,88x^2) + 0,55e^{-(0,29x)^2} \quad (15)$$

x : represents the width of the fabric in [cm]

$DS_{\text{weft}}(x)$: represents the weft dimensional stability of the VarB3 fabric in [%]

The precision of this model is given by the errors namely the relative error and the absolute error:

– Absolute error : $\Delta DS = 0,26$ [%]

– Relative error : $\frac{\Delta DS}{DS} = 6,1\%$

The curve representative of the evolution of dimensional stability in warp given by equation 15 is illustrated by figure 15:

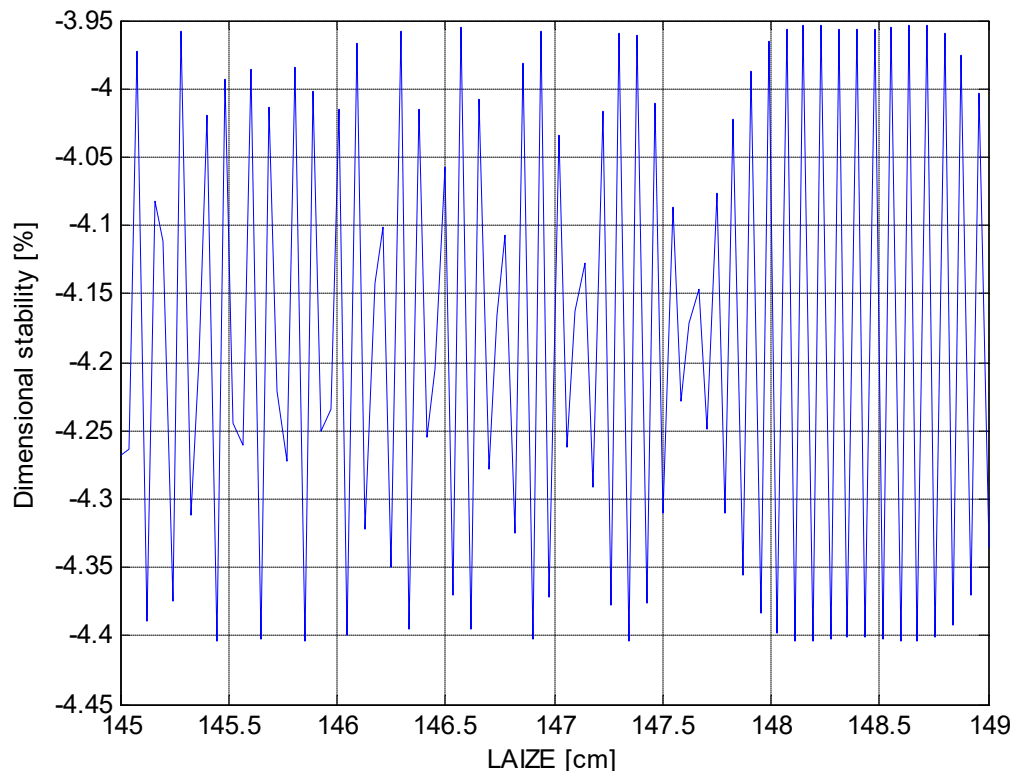


Fig. 15. Representative curve of equation 15

The curve illustrating the evolution of the dimensional stability in weft presented in Figure 15 shows an oscillation around the average value which is -4.2%. We notice two types of fabric groups in the result. The oscillation period of the dimensional stability of fabrics with a width less than 148 cm is lower than that greater than 148 cm. The respective values of the maximums and minimums are similar for both with -4.4% and -3.95%.

4) *Model of dimensional stability of white linen woven fabrics:*

- Warp model

By taking into consideration the 3 types of white woven fabric, we can give a general equation illustrating the evolution of the warp dimensional stability of white woven linen fabrics. This mathematical model is given by equation 16:

$$DS_{\text{w}}(x) = 1,47 * \sin(0,33x + 18,6) \quad (16)$$

x : represents the width of the fabric in [cm]

$DS_{\text{w}}(x)$: represents the warp dimensional stability of the white woven fabric in [%]

Equation (16) representing the model of the dimensional stability of the precision-dyed woven fabric whose values are given by the errors, namely:

- Absolute error : $\Delta DS = 0.034$ [%]
- Relative error : $\frac{\Delta DS}{DS} = 2.73\%$

The representative curve of equation 16 is given by figure 16:

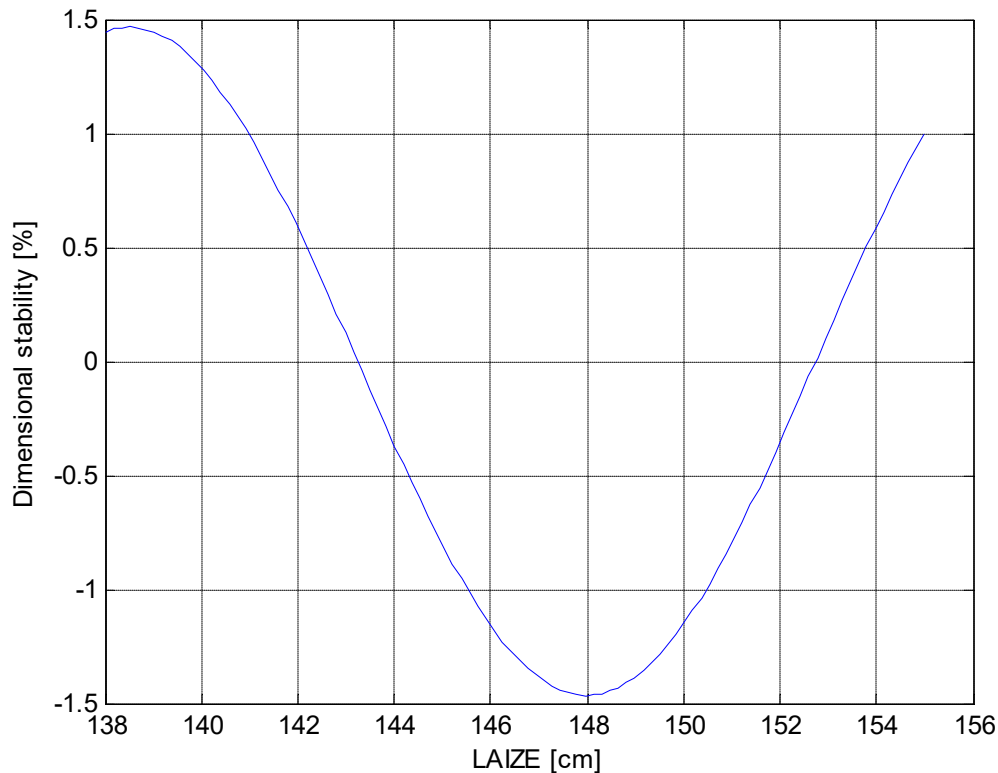


Fig. 16. Representative curve of equation 16

Based on the curve representative of the warp dimensional stability of white linen fabrics, we note that fabrics with a width between 143 cm and 153 cm tend to shrink and for others they tend to elongate after washing. However, the limits are largely respected.

- Weft model

With the 3 types of white woven fabric studied, namely VarB1, VarB2 and VarB3, we can give a general equation illustrating the evolution of the dimensional stability in the weft of white woven linen fabrics. This mathematical model is given by equation 17:

$$DS_{BT}(x) = 19,11 * \sin(2,7 * 10^{-3}x + 34,37) \quad (17)$$

x : represents the width of the fabric in [cm]

$DS_{BT}(x)$: represents the weft dimensional stability of the dyed woven fabric in [%]

The accuracy of equation (17) representing the weft dimensional stability model of balnc woven fabric is given by the errors, namely:

- Absolute error : $\Delta DS = 0.05$ [%]
- Relative error : $\frac{\Delta DS}{DS} = 1.26\%$

The representative curve of equation 17 is given by the following figure 17:

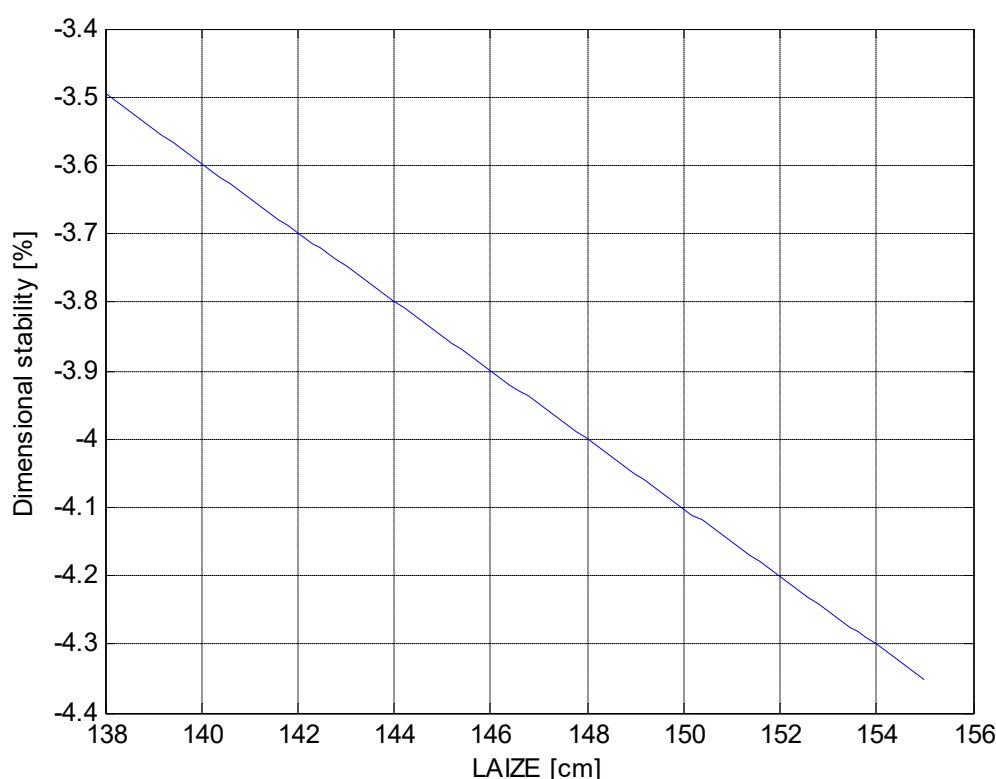


Fig. 17. Representative curve of equation 17

In Figure 17, we notice that the value of the dimensional stability in weft of white woven fabrics is inversely proportional to the width of the fabric. However, the dimensional stability model representing the white woven fabric is satisfactory and is justified by the very low relative and absolute error.

V. CONCLUSION AND PERSPECTIVES

To sum up, this article relates the mathematical models of the relationships between the dimensional stability of the fabric and its width for linen-based fabrics. To do this, we considered 2 types of fabric including dyed woven fabrics and white woven fabrics. Thus, three variants for each type of fabric were sampled. For each variant, mathematical models representing the dimensional stability in warp and weft of fabrics are developed in order to have an equation illustrating the two types of fabric.

The average value of the absolute errors of the models representing the error when stretching or shrinking the fabric is 0.038%. While the average relative error reflecting the accuracy of mathematical models of dimensional stability for linen fabrics is 1.15%.

As a perspective, it would be interesting to understand the phenomena of initiated tearing of linen fabrics.

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