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Correlation Between The Initiated Tear Of A Fabric And Its Constituent Yarns

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Abstract— This article represents the relationship between the initiated tearing of a fabric and the yarns's characteristics with which the fabric is made. There are several characteristics that were considered: the tensile strength of the yarns, the real metric number of the yarn, the elongation of the yarn, the kilometric resistance of the yarns and the hairiness index of the yarns. To better understanding this correlation, tests and experiments were carried out on the yarns and then during the making of the fabrics, we measured the initiated tearing of the fabrics. For a better appreciation of the results, a mathematical modeling of this correlation is presented in this work with possible precision errors which are expressed by the relative and absolute errors associated with each equation. The experiments carried out during the work were carried out with multitudes of yarns from different batches and origins.

Keywords— tear started, yarns, fabric, modeling, textile.

I. INTRODUCTION

Since the evolution of the textile world, users are increasingly looking for quality fabric that meets their respective requirements. Febrile tissue is tissue judged to be of poor quality. Initiated tearing of a tissue is the main parameter for evaluating tissue fever.

Knowing that the main element of the fabric is the yarns that constitute it. The parameters as well as the characteristics of these yarns have an impact on the quality of the fabric, in particular on the feverishness of the fabric produced. The yarns are defined by its metric number, its kilometric resistance but also by characteristics such as these imperfections.

In this article we will try to highlight the relationship between these yarn characteristics and the initiated tearing of a fabric. Thus, this work consists firstly to determine the characteristics of fabric's constituent yarns and secondly of evaluating the initiated tearing of the fabric produced. These relationships will be expressed by mathematical models.

II. METHOD FOR ASSESSING INITIATED TEAR

2.1. Principle of measuring the initiated tear

Initiated tissue tear represents the tearing force required to continue a defined length tear initiated by a cut in a sample by the application of an abrupt force. In general, the method for determining the initiated tear is carried out by the application of the Elmendorf method.

The principle for measuring the initiated tear consists of the use of a pendulum carrying a clamp which is aligned with a fixed clamp where the pre-cut piece of fabric is placed to measure the maximum force supported before rupture. When the pendulum is released, the movable jaw moves away from the fixed jaw and then the force which represents the tear is measured.

Therefore, the initiated tear represents the physical parameters of a fabric which allows us to know the fabric's resistance up to the point of tearing.

2.2. *Sampling method*

To have a better appreciation of the tear that has started, it is necessary to work with samples according to the rules of the art. There are four fundamental points for tissue sampling namely:

- For each sampling, two samples must be cut, one in the warp direction and the other in the weft direction.
- 5 sample pairs should be considered when sampling a fabric.
- Pairs of samples should not contain the same longitudinal or transverse yarns.
- No sample should be taken closer than 150mm from the edge of the fabric.

For instance, figure 1 illustrates an example of taking 5 pairs of samples from a tissue:

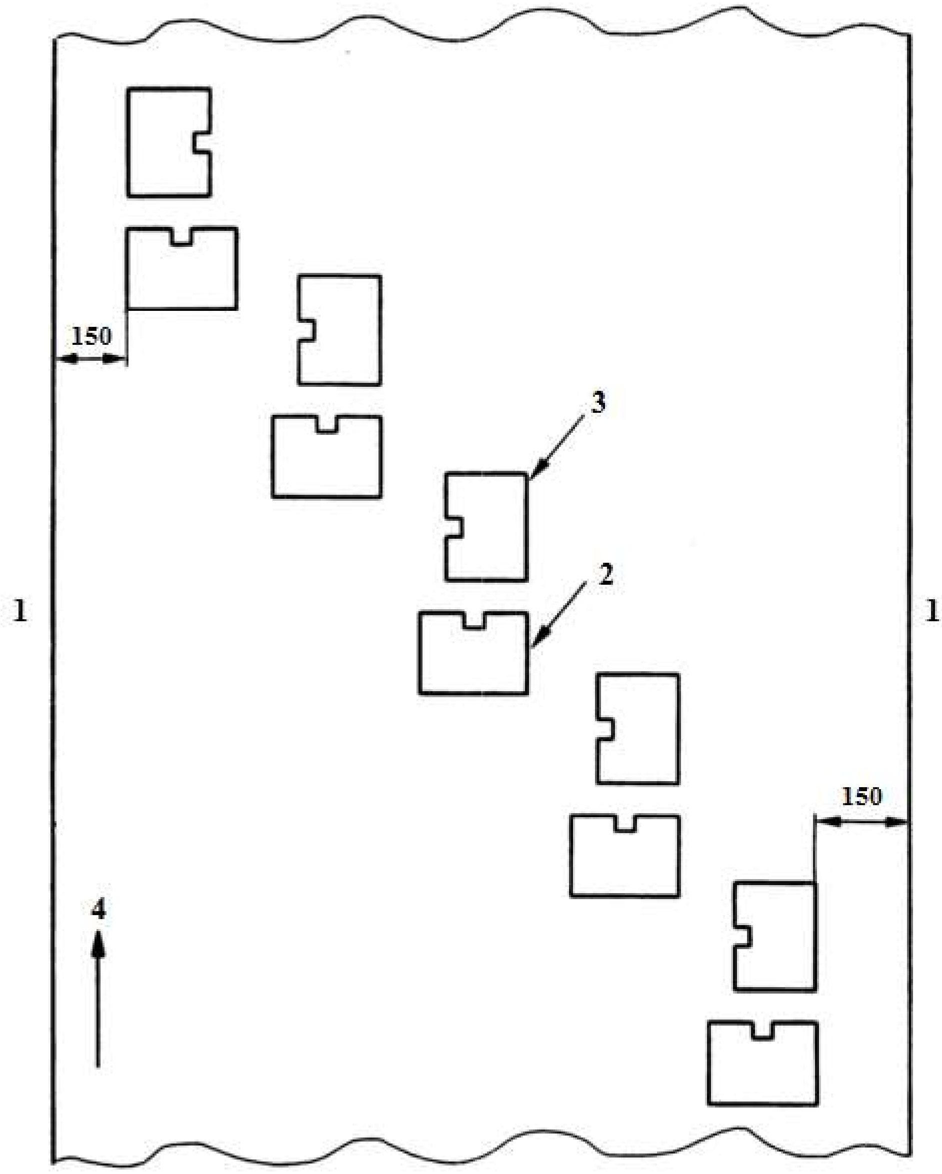

Fig. 1. Example of sampling a fabric

1: Edge;

2: Specimen for tear « across warp »;

3: Specimen for tear « across weft »;

4: Warp

The cutting dimension of the samples should be as shown in Figure 2:

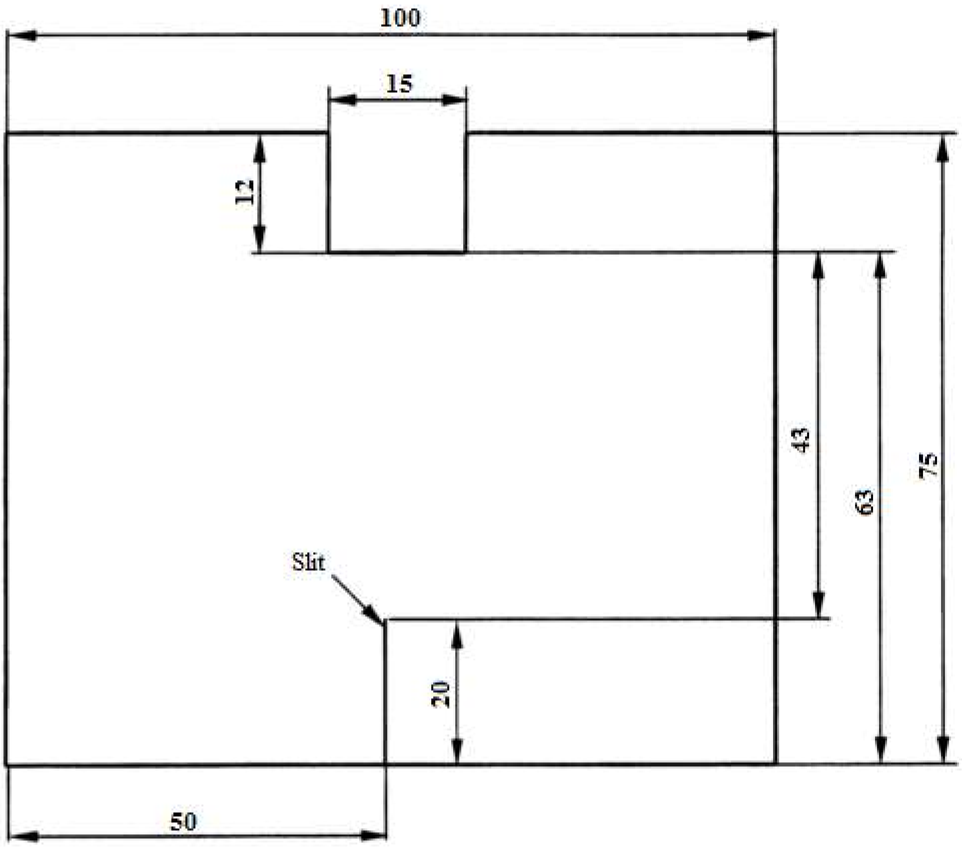

Fig. 2. Standard for cutting a sample

2.3. Calculation principle

When trying to measure the initiated tear of a sample, a mass must be chosen beforehand so that the measurement results will be between 15% and 85% of the full measurement scale. After releasing the pendulum, we can directly read the value of the force corresponding to the tearing force which will be dimensioned in Newtons [N]. In certain cases, depending on the type of device used, coefficients can be considered to obtain the value of the tearing force in Newtons.

The results of tear force for each direction should be rounded to two significant figures and it would be preferable to consider the arithmetic mean of the values obtained.

During our work, the values of the initiated tear are dimensioned in gram-force [gf] with 1 gf = 9.980665 mN.

III. PRESENTATION OF THE FABRIC

During our work, we considered a BCI blend fabric whose average fabric weight is 115 g/m2. Weft yarns and warp yarns are similar, and their overall characteristics are shown in Table 1 below.

It should be noted that this work aims to see the cause-effect relationships of the characteristics of the constituent yarns of the fabrics on the tearing force necessary to continue a tear of a defined length of a fabric.

Several specific yarn characteristics are dissected such as kilometric resistance, elongation, tensile strength, hairiness index, etc., in order to see their correlation with the initiated tearing of the fabric.

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

Settings	*Chain yarns*	*Weft yarns*
Coefficient of variation	***1,13***	***1,13***
Yarn density [/cm]	***42***	***31***
Imperfection	***71***	***71***
Spinning system	***Comb***	***Comb***

IV. PRESENTATION OF THE RESULTS

This work reflects the impact of the technical characteristics of the yarns on the tearing force necessary to continue a tear of a defined length of a fabric, also known as an initiated tear of a fabric. To do this, two tests are carried out during this work, the first one consists of analyzing the batches of yarns for making a fabric and the second one is the measurement of the force corresponding to the initiated tearing of the fabric. Therefore, the results presented in this work show the influence of the characteristics of the yarns on the initiated tearing of the fabric.

4.1. Relationship between initiated tear of fabric and tensile strength of yarn

4.1.1. Results on the warp direction of the fabric:

Figure 3 represents the relationship between the tensile strength of the yarn, the effective width of the fabric and the initiated tear of the fabric:

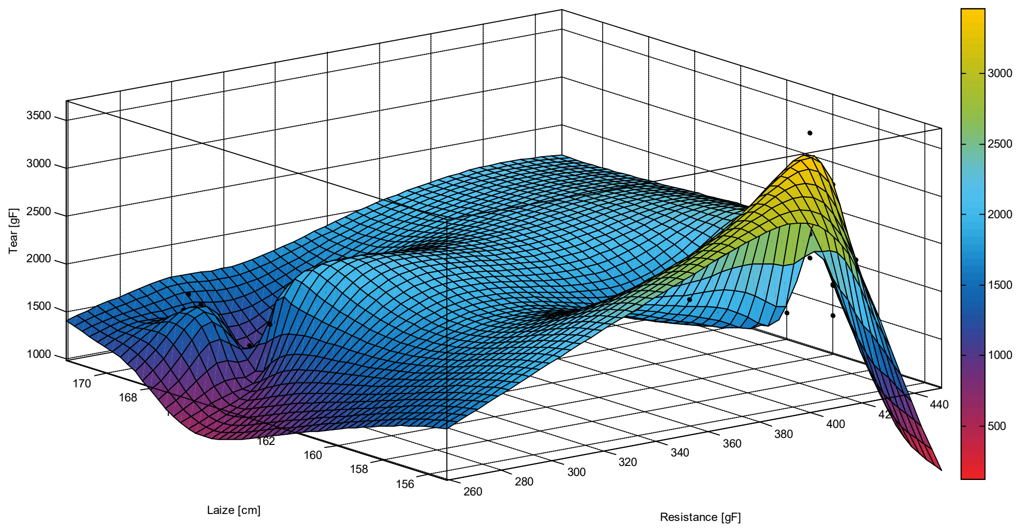

Fig. 3. Tear initiated in chain depending on resistance and width

Compared to the result obtained, we see that the value of the tear gradually increases with the resistance of the yarn. Equation 1 represents the relationship between the tear initiated in the warp direction of the fabric as a function of the strength of the yarn:

$$T(x) = -10^{-3}x^3 + 1{,}07x^2 - 352{,}8x + 39110 \qquad (1)$$

x: represents the resistance of the yarn in [gF]

T(x) : Chain-initiated tearing of the fabric [gF]

The characteristic curve of this equation is given by Figure 4:

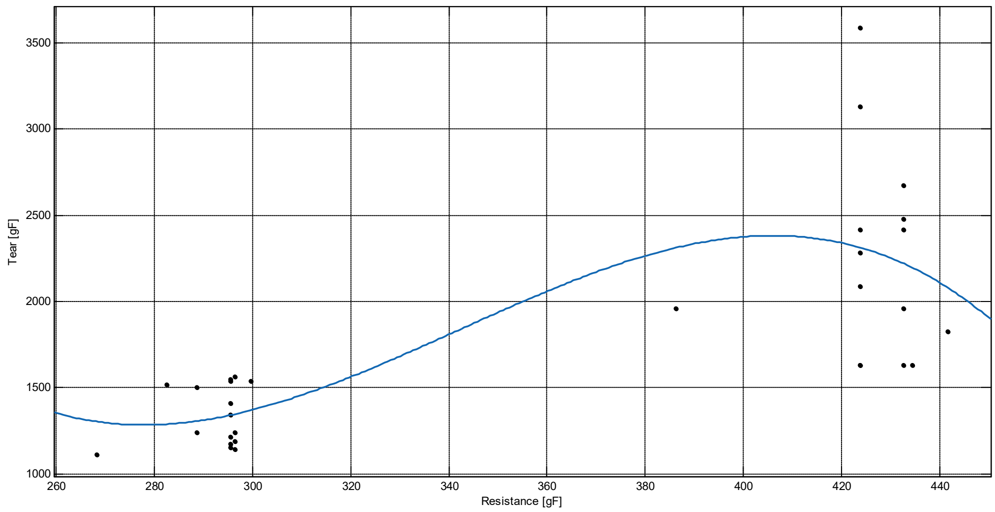

Fig. 4. Tear initiated as a function of resistance

The precision of this equation is defined by the respective absolute and relative errors:

– Absolute error : $\Delta DS = 101\ [gF]$

– Relative error : $\frac{\Delta DS}{DS} = 4{,}99\%$

4.1.2. Result in the direction of the fabric weft:

Figure 5 illustrates the relationship between the initiated tear, the useful width of the fabric and the resistance of the yarn for the test pieces taken following the weft direction of the fabric:

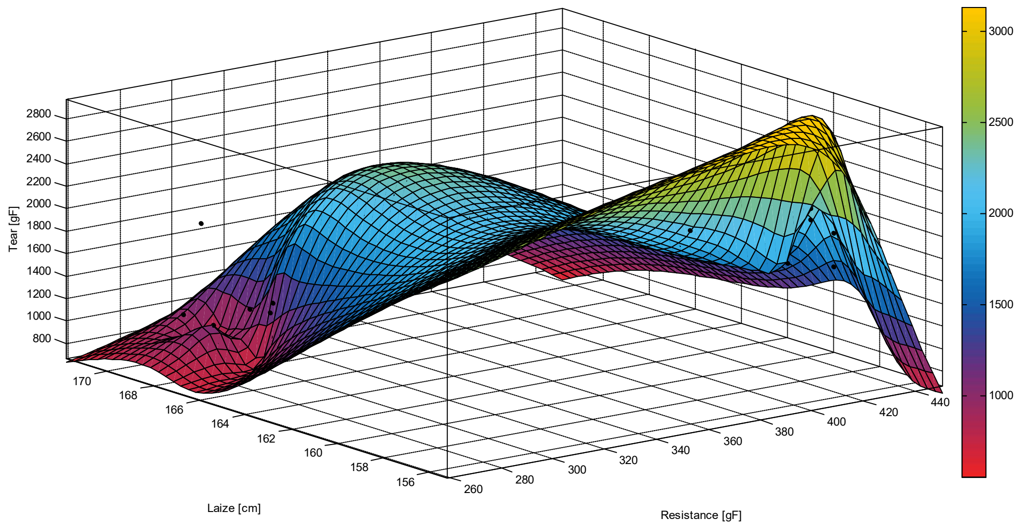

Fig. 5. Tear initiated in weft depending on resistance and width

The results in the direction of the weft are quite similar to that of the warp, the difference is found in the value of the slope of the curve. Equation 2 represents the relationship between weft-initiated tearing and yarn strength:

$$T(x) = -10^{-3}x^3 + 1{,}12x^2 - 362{,}3x + 38940 \quad (2)$$

x: represents the resistance of the yarn in [gF]

T(x) : Tear initiated in the weft of the fabric [gF]

Figure 6 illustrates the evolution of the tear initiated in weft presented by equation 2:

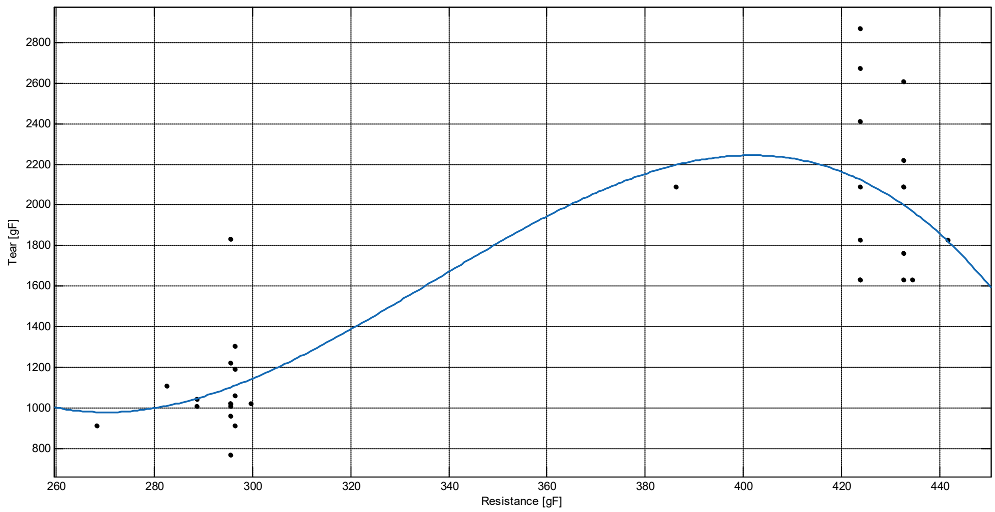

Fig. 6. Tear initiated in weft depending on the resistance of the yarn

The respective absolute and relative errors of equation 2 illustrated in Figure 6 are:

- Absolute error : $\Delta DS = 23{,}68\ [gF]$
- Relative error : $\frac{\Delta DS}{DS} = 1{,}28\%$

4.2. Relationship between the initiated tearing of the fabric and the elongation of the yarn

This section presents the results of the interdependence between the initiated tearing of the fabric and the increase in the length of the yarn which is caused by the breaking strength defined as the elongation of the yarn.

4.2.1. Results on the warp direction of the fabric:

The results related to fabric samples taken in the warp direction of the fabric are illustrated in Figure 7:

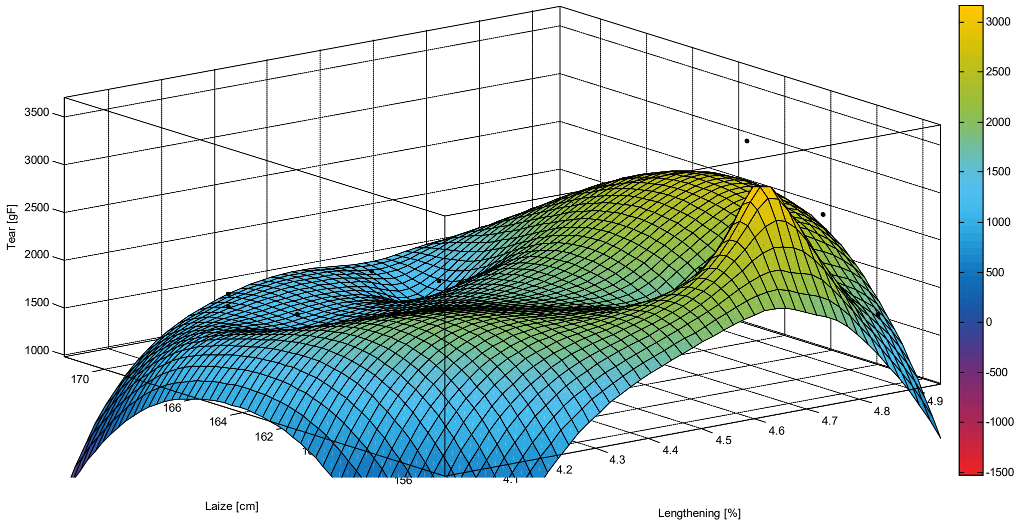

Fig. 7. Tear initiated in chain depending on the elongation of the yarn and the width

The previous figure illustrates the relationship between the initiated tearing of the fabric, the width of the fabric and the elongation of the yarn. We note that the higher the value of the yarn elongation, the greater the value of the initiated tear. However, the slope of this progression is small and the width of the fabric has no impact on the values of the initiated tear of the fabric. The link equation between the chain-initiated tear and the elongation of the yarn is given by the equation 3:

$$T(x) = 2735 \exp(-\left(\frac{x-5,5}{1,49}\right)^2) \qquad (3)$$

x: represents the elongation of the yarn in [%]

T(x) : Chain-initiated tearing of the fabric [gF]

Figure 8 illustrates the evolution of the chain-initiated tear presented by equation 3:

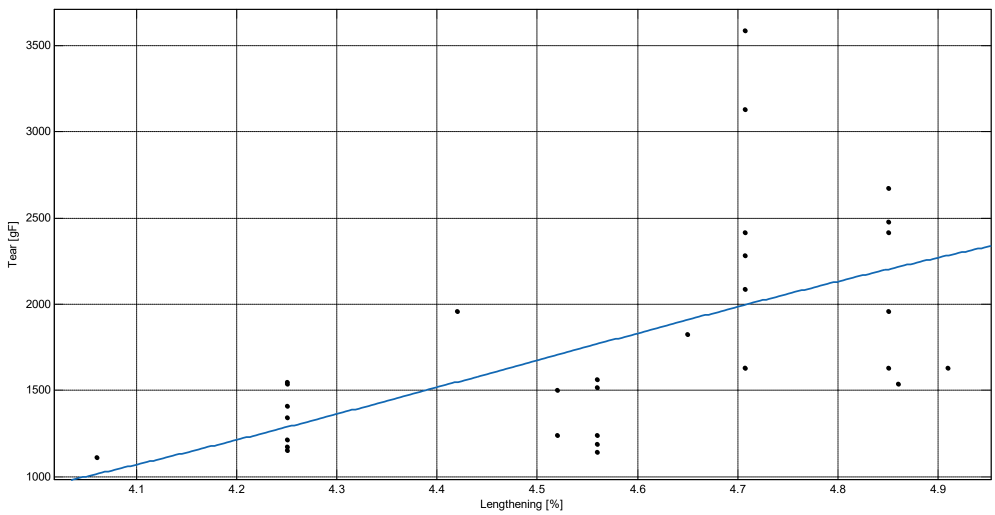

Fig. 8. Tear initiated in chain depending on the elongation of the yarn

Equation (3) which shows the tear initiated as a function of the elongation of the yarns has the precision illustrated by the errors whose values are:

- Absolute error : $\Delta DS = 50{,}26\ [gF]$
- Relative error : $\frac{\Delta DS}{DS} = 2{,}45\%$

4.2.2. Results on the weft direction of the fabric:

The results related to fabric samples taken in the weft direction of the fabric is shown in Figure 9:

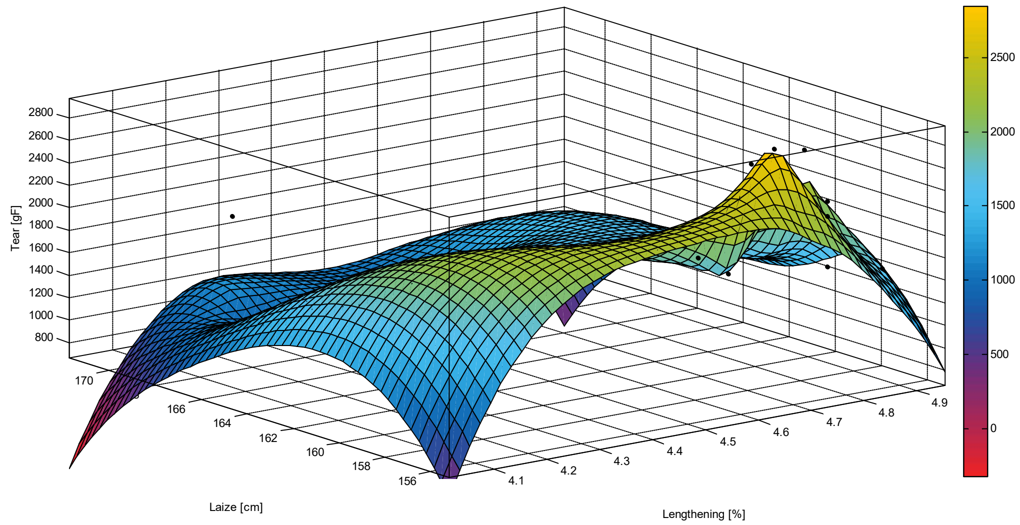

Fig. 9. Tear initiated in the weft depending on the elongation of the yarn and the width of the fabric

The variation of the tear initiated in the direction of the fabric weft is quite similar to that of the warp however the slope value is slightly lower compared to that of the warp. Equation 4 illustrates the evolution of the tear initiated in the weft as a function of the elongation of the yarn:

$$T(x) = 2196\,\exp(-\left(\frac{x-5{,}27}{1{,}21}\right)^2) \qquad (4)$$

x: represents the elongation of the yarn in [%]

T(x) : Tear initiated in the weft of the fabric [gF]

Figure 10 illustrates the evolution of the tear initiated in weft presented by equation 4:

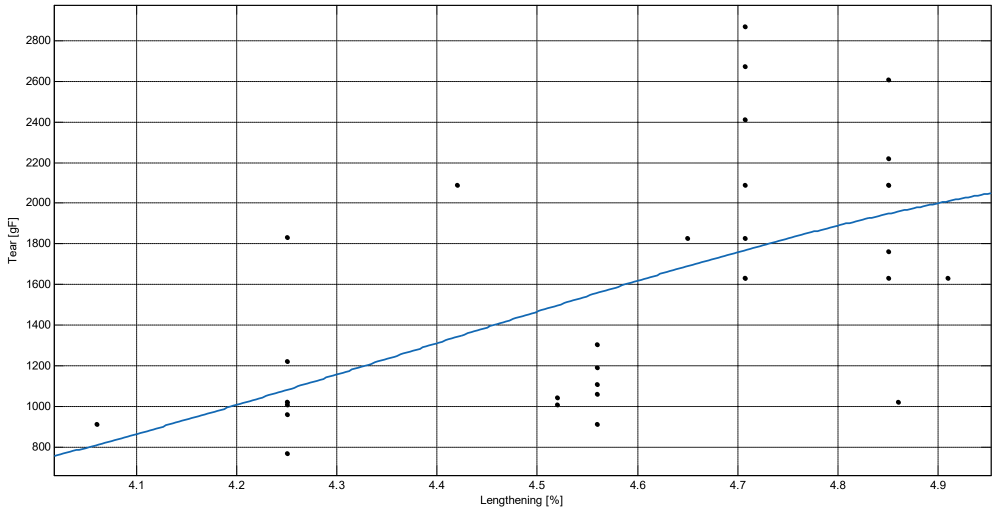

Fig. 10. Tear initiated in weft depending on elongation

Equation (4) which illustrates the tear initiated in the weft as a function of the elongation of the yarns has the precision illustrated by the errors whose values are:

- Absolute error : $\Delta DS = 42{,}16\ [gF]$
- Relative error : $\frac{\Delta DS}{DS} = 2{,}48\%$

4.3. Relationship between the initiated tearing of the fabric and the kilometer resistance of the yarn

The kilometric resistance of the yarn (RKM) corresponds to the number of kilometers of yarn necessary to suspend from a yarn so that it breaks under its own weight. In this section explains according to the experiments the relationship between the RKM of the yarn and initiated tearing of the fabric.

4.3.1. Result in the warp direction of the fabric

Figure 11 represents the results of samples taken in the warp direction of the fabric. This figure shows the relationship between the initiated tearing of the fabric, the useful width and the kilometric resistance of the yarn.

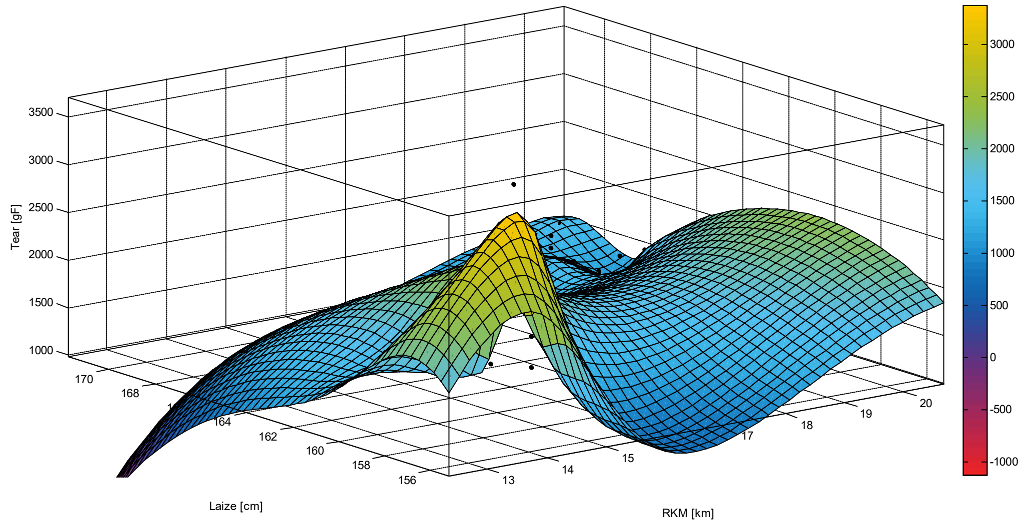

Fig. 11. Tear initiated in chain depending on RKM and width

We note that the average value of the initiated tear of the fabric decreases with the increase in the value of the kilometric resistance. Equation 5 represents the relationship between the tear initiated in the warp direction as a function of the kilometric resistance of the yarn:

$$T(x) = 15x^3 - 776{,}5x^2 + 1{,}26 * 10^4x - 6{,}43 * 10^4 \quad (5)$$

x: represents the RKM of the yarn in [km]

T(x) : Chain-initiated tearing of the fabric [gF]

Figure 12 illustrates the evolution of the chain-initiated tear as a function of the RKM presented by equation 5:

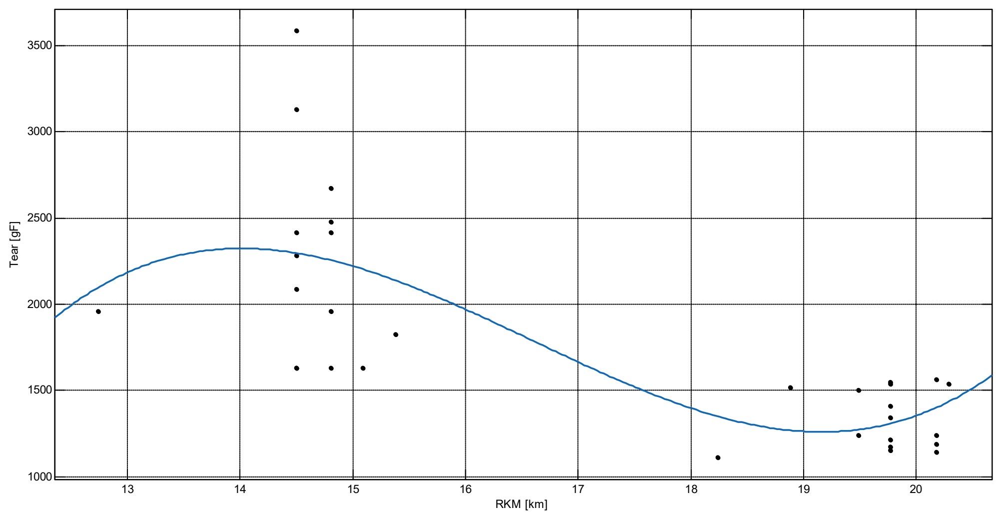

Fig. 12. Tear initiated in chain according to the RKM of the yarn

The respective absolute and relative errors linked to equation (5) are:

- Absolute error : $\Delta DS = 8{,}48\ [gF]$
- Relative error : $\frac{\Delta DS}{DS} = 0{,}38\%$

4.3.2. Result in the weft direction of the fabric

Figure 13 implies the results of samples taken in the weft direction of the fabric. This figure shows the relationship between the initiated tear of the fabric, the useful width of the fabric and the kilometric resistance of the yarn.

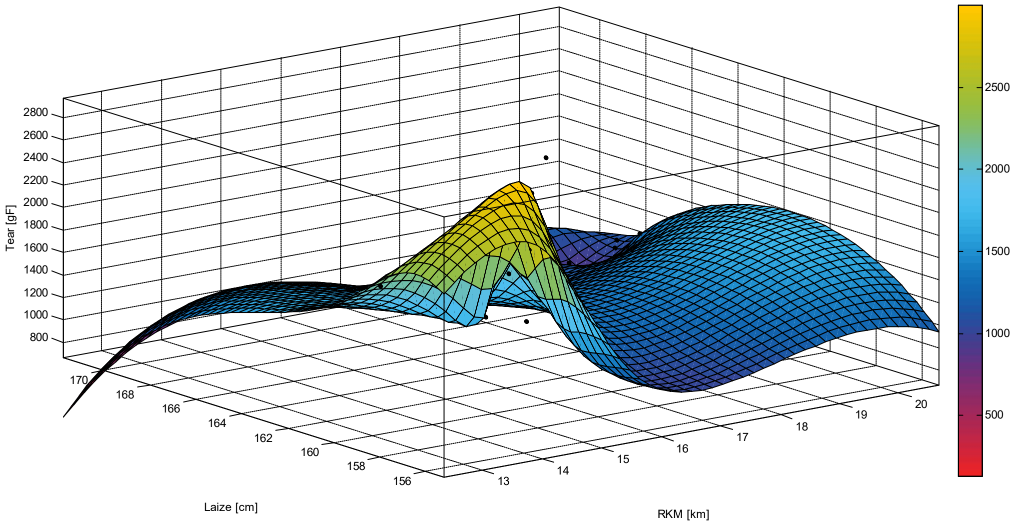

Fig. 13. Tear initiated in weft depending on the RKM of the yarn and the width

The results obtained on the weft part of the fabrics show that the evolution of the initiated tear is similar to that of the warp part. Equation 6 represents the evolution of the tear initiated in the weft as a function of the kilometric resistance:

$$T(x) = 12{,}73x^3 - 620{,}3x^2 + 9764x - 4{,}79 * 10^4 \quad (6)$$

x: represents the RKM of the yarn in [km]

T(x) : Tear initiated in the weft of the fabric [gF]

Figure 14 represents the evolution of the tear initiated in weft as a function of the RKM presented by equation 6:

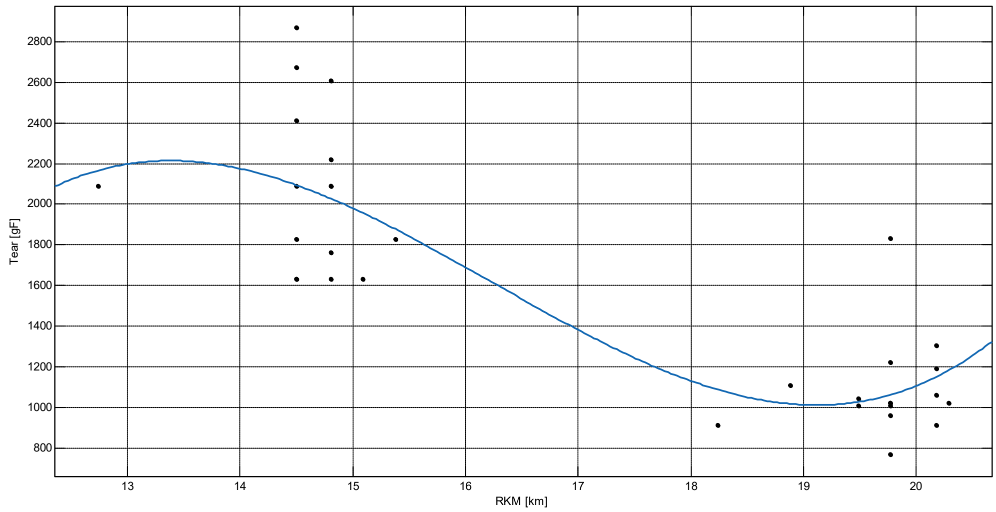

Fig. 14. Tear initiated in weft as a function of yarn RKM

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

- Absolute error : $\Delta DS = 13{,}89\ [gF]$
- Relative error : $\frac{\Delta DS}{DS} = 0{,}66\%$

4.4. Relationship between the initiated tear of the fabric and the actual metric number of the yarn

The metric number corresponds to the length of one gram of yarn. This part reflects the relationship between the metric number also known as the count of a yarn and the initiated tear of the fabric.

4.4.1. Result in the warp direction of the fabric

Figure 15 represents the relationship between the initiated tear, the actual metric number of the yarns and the useful width of the fabrics for samples taken in the warp direction of the fabric:

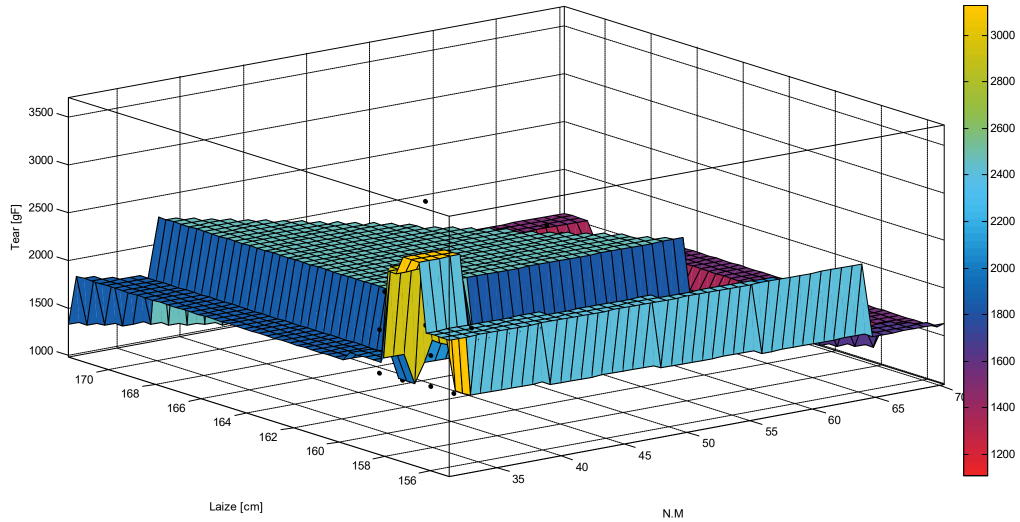

Fig. 15. Tear initiated in chain depending on the N.M and the width

We note that the average value of the tear initiated in the chain is inversely proportional to the metric number of the yarn. Equation 7 translates the relationship between initiated tear and yarn count:

$$T(x) = -0{,}013x^3 + 0{,}048x^2 + 69{,}62x + 310{,}4 \qquad (7)$$

x: represents the N.M (TITLE) of the yarn

T(x) : Chain-initiated tearing of the fabric [gF]

Figure 16 illustrates the representative curve of equation 7:

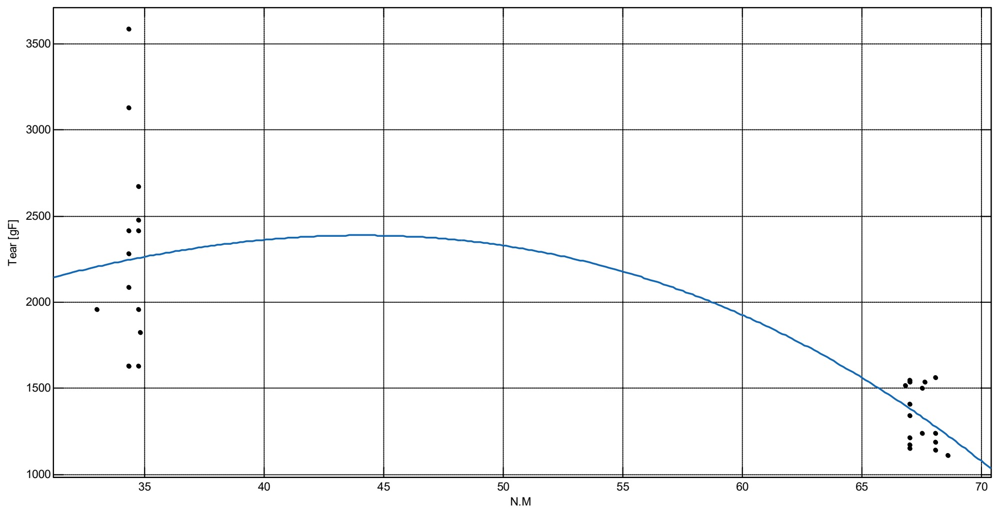

Fig. 16. Tear initiated in chain depending on the N.M of the yarn

The respective absolute and relative errors linked to equation (7) are:

– Absolute error : $\Delta DS = 2{,}43\ [gF]$

– Relative error : $\frac{\Delta DS}{DS} = 0{,}11\%$

4.4.2. Result in the weft direction of the fabric

Figure 17 represents the relationship between the initiated tear, the actual metric number of the yarns and the effective width of the fabrics for samples taken in the weft direction of the fabric:

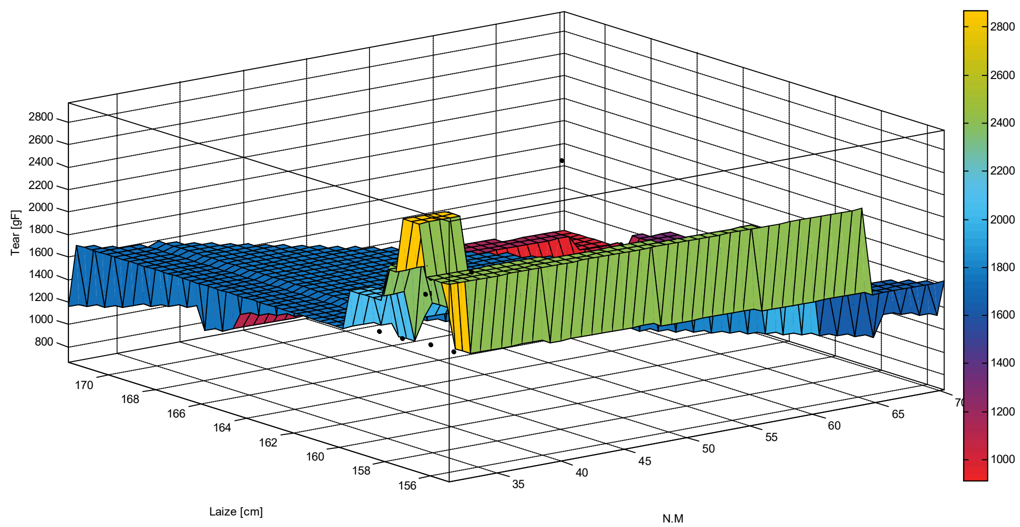

Fig. 17. Tear initiated in weft depending on the N.M of the yarn of the width of the fabric

We notice the trend of the curve for the weft is similar to that of the warp. For samples with a high useful width, the slope of decline of the initiated tear is low. Equation 8 represents the connection between the tear initiated in the weft and the N.M of the yarn:

$$T(x) = -0{,}11x^3 + 17{,}21x^2 - 928{,}4x + 1{,}8 * 10^4 \quad (8)$$

x: represents the N.M (TITLE) of the yarn

T(x) : Tear initiated in the weft of the fabric [gF]

Figure 18 illustrates the representative curve of equation 8:

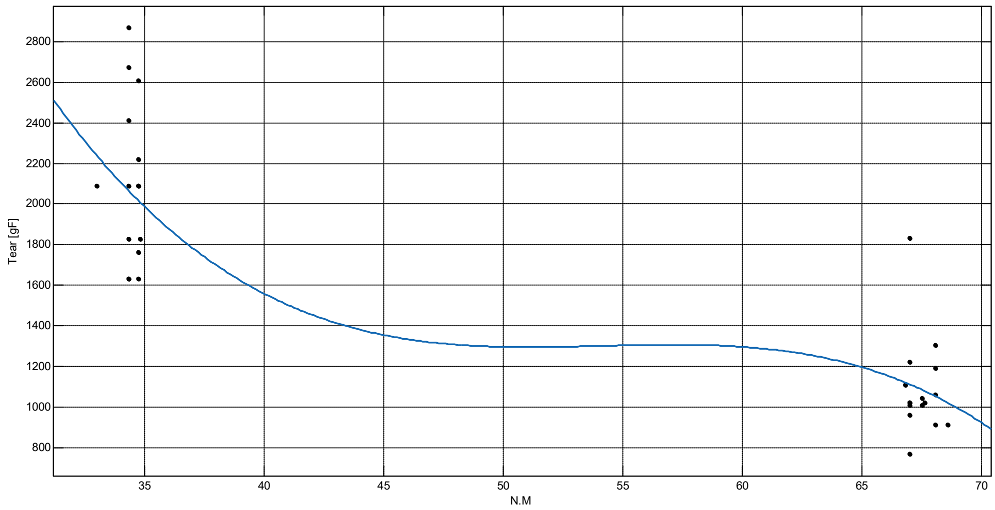

Fig. 18. Tear initiated in the weft of the fabric depending on the N.M of the yarn

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

- Absolute error : $\Delta DS = 10{,}72\ [gF]$
- Relative error : $\frac{\Delta DS}{DS} = 0{,}52\%$

4.5. Influence of the hairiness index of the yarns on the initiated tearing of the fabric

The hairiness index corresponds to the total length of fibers released from 1 cm of yarn. This paragraph reflects the relationship between the hairiness index of the yarn and the initiated tearing of the fabric.

4.5.1. Result in the warp direction of the fabric

Figure 19 represents the relationship between the hairiness index of the yarn, the useful width and the initiated tear of the fabric:

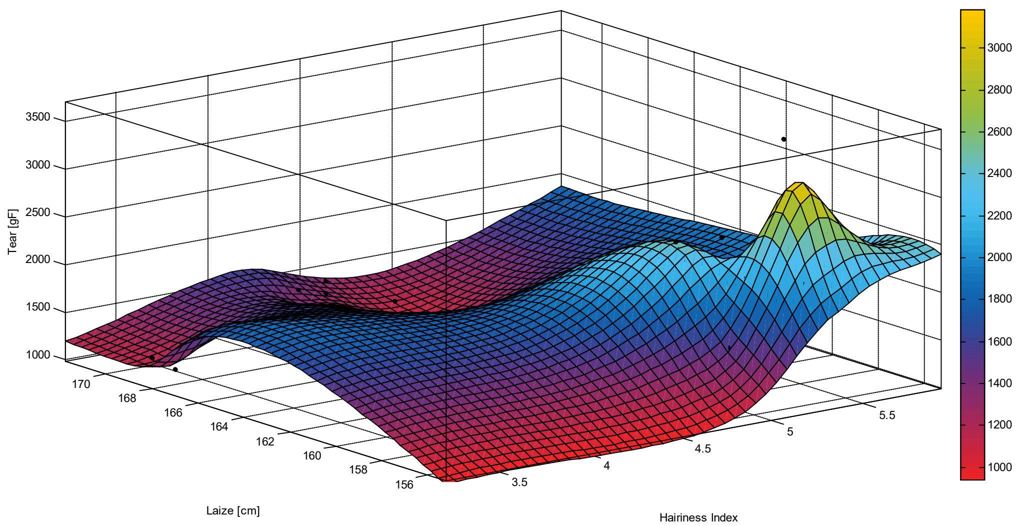

Fig. 19. Tear started in chain according to I.P and width

We notice the tear started in chain gradually evolving with the hairiness index of the yarns. For fabrics with large widths, the value of the initiated tear is quite high compared to the average, the trend of evolution is similar to others. Equation 9 shows the relationship between the initiated tear and the I.P of the yarn:

$$T(x) = -709{,}5x^3 + 9749x^2 - 4{,}33 * 10^4 x + 6{,}37 * 10^4 \quad (9)$$

x: represents the hairiness index of the yarn

T(x) : Chain-initiated tearing of the fabric [gF]

Figure 20 illustrates the representative curve of equation 9:

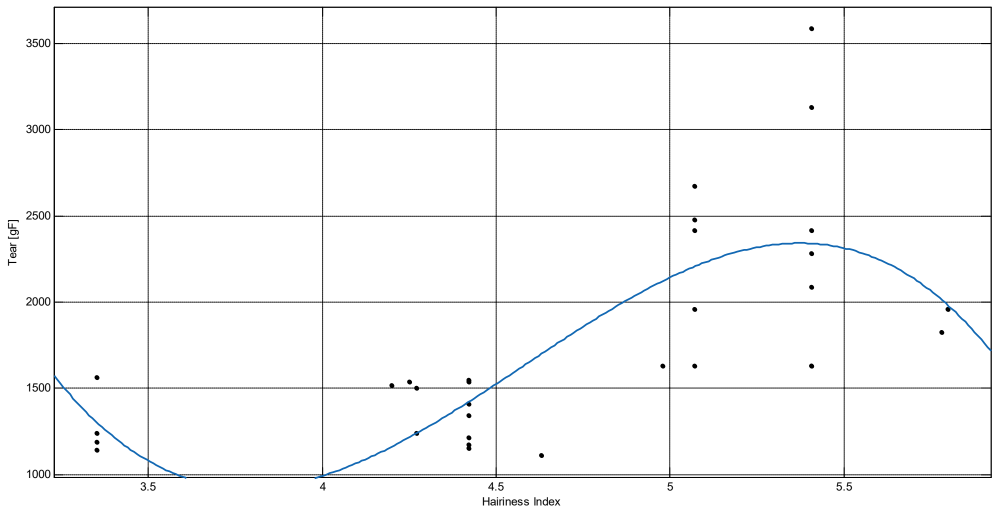

Fig. 20. Tearing initiated in a chain depending on the hairiness index

The respective absolute and relative errors linked to equation (9) are:

- Absolute error : $\Delta DS = 1{,}54\ [gF]$
- Relative error : $\frac{\Delta DS}{DS} = 0{,}07\%$

4.5.2. Result in the weft direction of the fabric

Figure 21 represents the relationship between the hairiness index of the yarn, the useful width and the initiated tear for samples taken in the direction of the weft of the fabric:

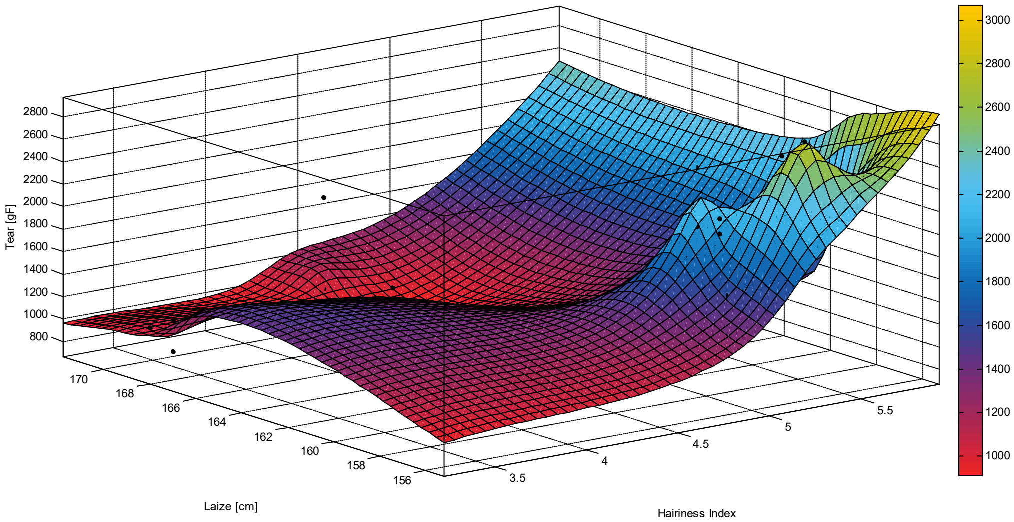

Fig. 21. Tear initiated in weft depending on the I.P and width

The progression trend of the curve for the tear initiated in weft is similar to that in warp but the slope is greater. Equation 10 illustrates the influence of the hair index on the initiated tearing of the fabric:

$$T(x) = -604{,}7x^3 + 9019x^2 - 4{,}06 * 10^4 x + 6{,}02 * 10^4 \quad (10)$$

x: represents the hairiness index of the yarn

T(x) : Tear initiated in the weft of the fabric [gF]

Figure 22 illustrates the representative curve of equation 10:

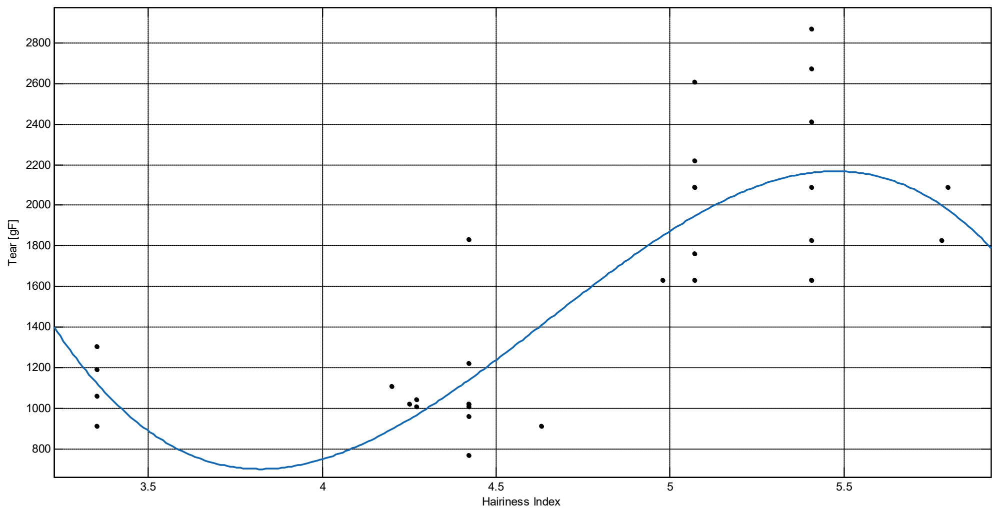

Fig. 22. Tear initiated in weft depending on the I.P of the yarn

The absolute and relative errors associated with equation 10 are:

- Absolute error : $\Delta DS = 21{,}38\ [gF]$

- Relative error : $\frac{\Delta DS}{DS} = 1{,}04\ \%$

V. Conclusion and perspectives

This article reflects the experimental realization of the interdependence between the tearing force required to continue a defined length tear of a fabric and the characteristics of the yarns such as strength, hairiness index, actual metric number and strength kilometer. During this work, the constituent yarns of the fabrics were analyzed according to the rules of the art, and then, making the fabrics we measured the value of the tearing force initiated according to the standards.

The results which reflect the relationship between each yarn characteristic and the initiated tear are modeled by equations after interpolation and defined with their precisions are reflected by the absolute and relative errors.

Subsequently, it would be possible to study the correlation between fabric treatment parameters such as heat fixation and the characteristics of the yarns which constitute the fabric.

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