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Modeling The Thermofixation Parameters Of A Lycra Fabric

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Abstract — **This article describes the ideal conditions for heat-fixing a cotton-lycra-based fabric. Indeed, the heat setting process has an impact on the technical parameters of the fabrics, such as tensile strength, initiated tearing, elasticity and remanence. Knowing that fabrics containing lycras are delicate in terms of dimensional stability, the interest of this article is to contribute to the control of heat setting parameters with the aim of having optimal dimensional stability of fabrics. To do this, we considered 3 types of fabrics containing elastanes with different composition. From the tests and tests carried out, we obtained the ideal parameter values (including temperature and speed) for the heat fixing of fabrics.**

Keywords — **Dimensional Stability, Spandex, Shrinkage, Thermofixation, Textile.**

I. Introduction

With human and technological evolution, the technical requirements of customers in the textile field continue to evolve. To have quality products in order to satisfy well-being as human comfort, the techniques and processes of manufacturing fabrics are often pushed to their limit during the manufacture of fabrics.

Among the main processes involved in the manufacturing of fabrics containing elastane is heat setting. Parameters for the smooth running of the process must be controlled, namely temperature and speed. Knowing that these values contribute greatly to the quality of fabrics and respect for the dimensional stability of fabrics.

Then, this article then focuses on the control of heat setting parameters which will have direct impacts on the dimensional stability of the fabric. To do this, we were interested in the impact of the temperature and the speed of heat setting on the physical test carried out on the fabrics such as tensile strength, initiated tearing, elasticity and persistence. Three (03) samples were taken, such as the fabric containing 1%, 2% and 3% elastane.

II. Methodology

2.1 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 constraints 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.

Thermo-setting is:

- a thermal and mechanical process
- Intended to guarantee the size accuracy and dimensional stability of textile materials.

Textile construction imposes constraints on the textile. Stresses arise from the arrangement of dipolar bonds and hydrogen bonds, as well as crystallization and chain rigidity.

During the Thermo-setting process:

- these internal constraints are reorganized.
- The dimension of textiles is changing.
- Depending on the material, different heat setting methods, such as saturated steam or hot air, are used for fixing.

The standard method for heat setting synthetic material is the permanently used stenter frame (widening frame). Stenter frame heat is created using hot air. Important process parameters are temperature, residence time, width and boost. For natural fiber relaxation dryers, crimping and steam treatment units are used.

Heat setting is an expensive and energy-intensive textile process. Correlation of heat setting parameters is analyzed to determine process optimization potential. Optimal dimensional stability models have been obtained for cotton/elastane woven fabrics.

2.2 Physical tests linked to the stability and resistance of tissues

2.2.1 Resistance:

To evaluate the resistance of the fabric it is important to carry out a dynamometric study. In that case, a rectangular test piece must be placed between two clamps, one clamp is fixed, the other is mobile and moves at constant speed in order to apply a tensile force on the fabric. The measuring cell transfers the data to the computer which then provides us with a force curve as a function of elongation on which we can record or calculate the breaking strength, the breaking stress, the maximum deformation, the energy required to the break and Young's modulus.

Resistance is:

- One of the physical parameters of a fabric which allows us to know the resistance of a fabric to traction.
- A stability reference dimensioned in kilogram force [KGF]

The equipment used is the constant speed dynamometer of elongation. (constant-rate-ofextension (cre)) machine hounsfield. Knowledge of tensile strength allows us to control the actions applied to fabrics to control its final dimension.

2.2.2 Tear started :

To study the initiated tear, we must use 2 pendulums where we place the pre-cut piece of fabric to measure the maximum force supported before rupture. The result is displayed and interpreted in relation to the customers' standard.

The tear that has begun is:

- Also physical parameters of a fabric which allows us to know the resistance of a fabric up to the point of tearing.
- A stability reference dimensioned in Newton [N]

The material used is the Elmendorf tear tester. Knowledge of the initiated tear allows us to control the actions applied to the tissues to control its final dimension so that the tissue will not be feverish.

2.2.3 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.

2.3 Operating methods

In our research we will put the fabrics containing different quantities of lycra through the expander ream by varying the temperature and speed for variations and possible combinations to have a more stable fabric. Here are the standards we will use:

- For resistance: We will take 50 Kgf as peak value
- For the started tear: we will take a maximum value of 1631 Kgf
- For shrinkage: Before heat setting, most fabrics containing Lycra have a high shrinkage value of more than -10% and the norm is 0 to -5 or 0 to -3 for some**.**

Indeed, if we talk about shrinkage, fabrics containing elastic fibers have a very high shrinkage value before being heat set (almost all above -10 in warp and weft). Each customer has their own tolerance in relation to the latter (from 0 to - 3 or from 0 to - 5). We carry out our tests in the lab as far as to satisfy these requests.

Here are the stages of our study:

- We will vary the temperature and keep the speed constant for each fabric containing between 1 to 3% lycra.
- We will vary the speed and maintain the temperature
- We will vary the width of the fabric and keep the temperature and speed

III. Presentation Of The Fabric

During this work we considered 3 samples of cotton/lycra-based fabric. Note that Lycra is one of the best alternatives for having a mix between a chemically polyurethane fiber and natural fibers such as cotton, wool, and silk. In most cases, fabrics containing elastane are used for making indoor and outdoor clothing but also for sports clothing. The major advantages of lycra over other fibers of the same type are its lightness and its non-decomposition when exposed to perspiration, oil, lotions or body detergents. The most used mixture for the textile and knitting industries is the cotton/Lycra mixture.

The tissues studied in this work are:

– Composed of 99% cotton and 1% elastane, density 235 g/m^2 and useful width 135 cm. The fabric is sateen. The warp threads are metric number 50p 100% cotton and the weft threads are 34C+34E.

– Composed of 98% cotton and 2% elastane, density 110 g/m^2 and useful width 146 cm, it is a plain fabric. The warp threads have the metric number 85P 100% cotton and the weft threads are 100E.

– Composed of 97% cotton and 3% elastane, density 235 g/m^2 and useful width 135 cm, it is a fabric made with a TWILL 3-1 weave. The warp threads have a metric number of 50P 100% cotton and the weft threads are 34E.

The wire characteristics used during fabric development are illustrated in Table 1 bellow:

TABLE I. CHARACTERISTIC OF WARP AND WEFT YARN .

Metric number	50P	34E	34C	100E	85P
CV	1,58	1,7	1,28	2,02	1
finesse	0	0	0	12	2
size	2	7	71	46	18
NEPS	40	7	98	73	63
Irregularity	9,32	8,87	10,63	11,11	10,05
RKM	17,19	15,37	16,96	21,68	20,54
CV (RKM)	7,71	8,4	7,93	11,9	8,31
Elongation	4,62	7,87	5,25	6,27	4,29
CV (Elongation)	7,93	8,93	8,18	10,33	10,12
IP	5,46	6,69	8,3	3,72	3,57

Table 3 illustrates the technical characteristics of the weft yarn:

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

IV. PRESENTATION OF THE RESULTS

The aims of our study is to determine the optimal parameters of the expander frames such as the temperature and processing speed during Thermo-setting in order to have a fabric that is both stable and resistant. To do this, we varied the speed and temperature of the treatment in order to obtain the optimal parameters suitable for the heat setting of fabrics containing elastanes.

4.1 Results in relation to dimensional stability

4.1.1 Influence of temperature and speed on dimensional stability:

Figure 1 illustrates the dimensional stability in chain after varying the temperature and speed of the expander ream during thermo-setting:

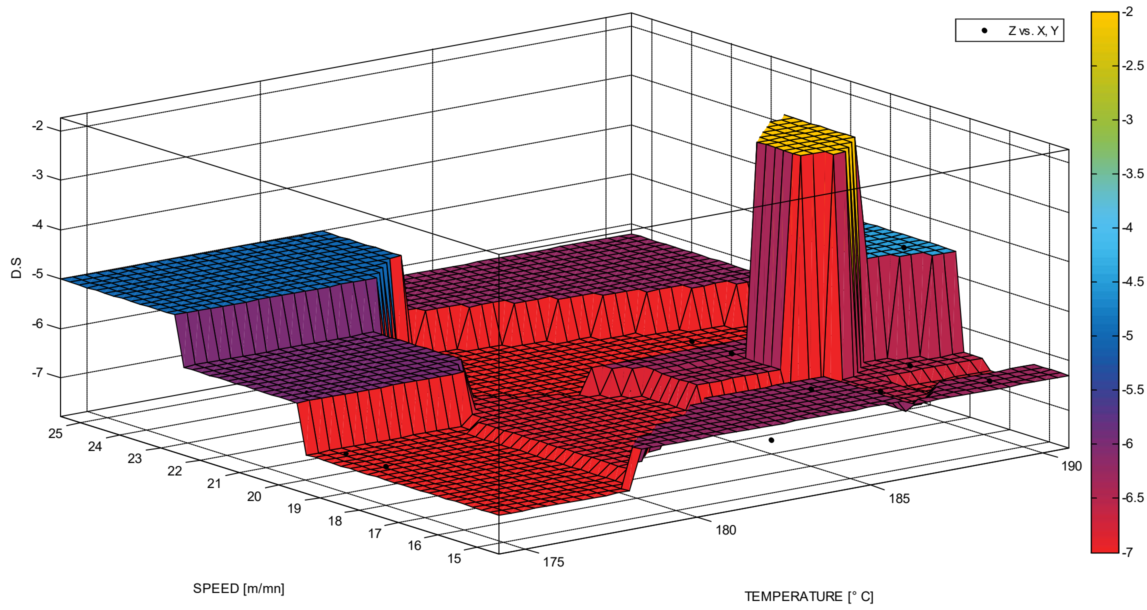

Fig. 1. Dimensional stability in chain

The dimensional stability of a fabric is quite delicate because many parameters come into play (tension on the machine, ambient air temperature, previous treatments of the fabric, etc.). In this case, we could not jump to a conclusion but it takes a lot of testing. Here, we see that whatever the speed, the chain withdrawal varies around -5 and has a limit of -7. We see from these results that the more the speed increases, the fabric is more stable. Note that if the speed is too high, for example greater than 20 m/min, we will have higher shrinkage values because the residence time is short and the elastic fibers are still as elastic which leads to a higher shrinkage value.

For the case of the weft side of the fabric, the dimensional stability is illustrated in Figure 2:

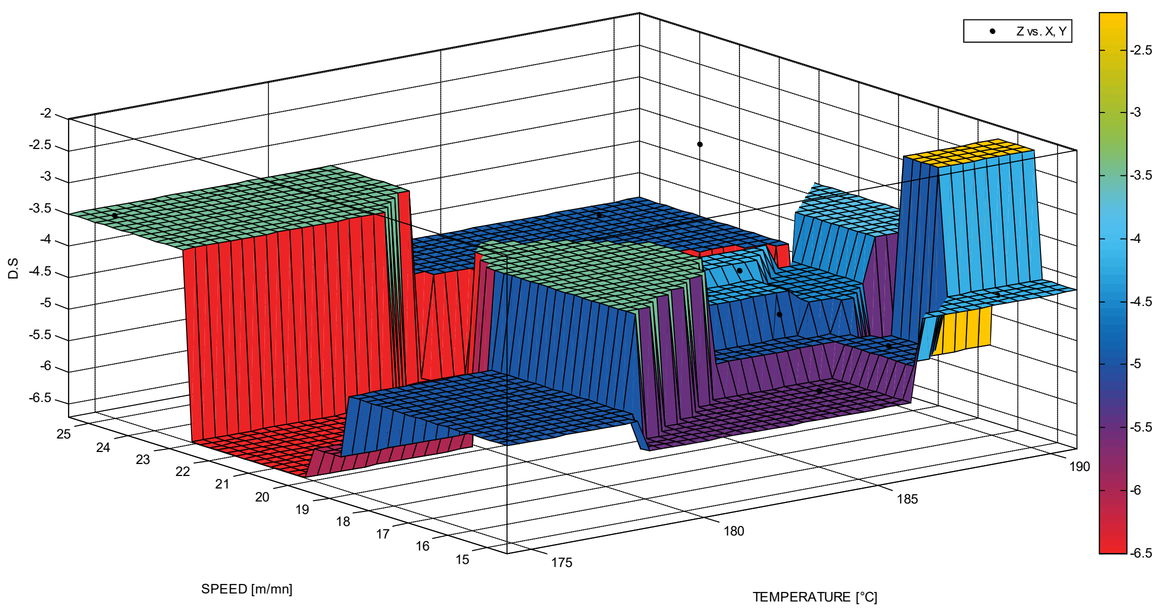

Fig. 2. Dimensional stability in weft

The result of the dimensional stability of the weft side of the fabrics is quite similar to that of the warp. However, it is necessary to take into account the resistance of the elastic fiber of the fabric because the use of an excessive temperature in the expander reams during heat setting could risk damaging the fabrics and would causes a loss of several properties of the fiber including the elasticity.

4.1.2 Standard heat setting equation for dimensional stability:

The evolution of the warp dimensional stability of the fabric as a function of the temperature and the speed of the expander ream is illustrated by equation 2:

$$D.S_C(x,y) = -6{,}93 + 0{,}37\sin(2{,}92xy) + 10^4 e^{-(0{,}27y)^2} \qquad (2)$$

- D.S: Dimensional stability in [%]
- x : Temperature in [°C]
- y : Speed [m/mn]

This equation has an absolute error that we show below:

This equation has an absolute error of ΔD.S = 0,69 Cm with a relative error $\frac{\Delta D.S}{D.S} = 10{,}64\ \%$

On the weft side of the fabrics, the evolution of dimensional stability as a function of speed and temperature is given by the expression (3):

$$D.S_w(x,y) = -4{,}59 - 0{,}28\sin(0{,}58xy) - 9{,}83e^{-(0{,}74y)^2} \qquad (3)$$

The precision of this equation is illustrated by the errors below:

- Absolute error: ΔD.S = 0,55 Cm
- Relative error: $\frac{\Delta D.S}{D.S} = 13{,}64\ \%$

4.2 Results in relation to resistance

4.2.1 Influence of temperature and speed on fabric resistance

During our study, the influence of temperature and speed on the resistance of the fabrics was carried out both on the warp and weft side of the fabric. Figure 3 represents the evolution of the chain resistance of the fabric as a function of temperature and speed:

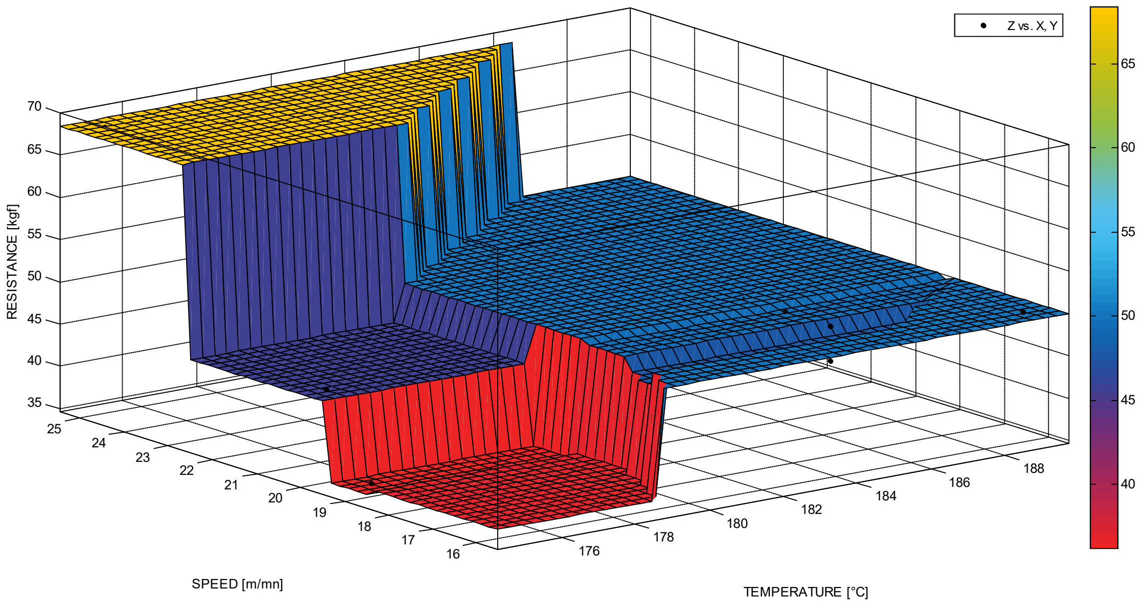

Fig. 3. Chain resitance of the fabric

If we keep the temperature constant and we increase gradually the speed, then we have increasing resistance. The latter is due to the reduction in the residence time in the machine because the more the speed increases, the passage time in shorter. Note that temperature plays a key role in our study, it allows us to reduce the resistance of fabrics containing elastic fiber, which is favorable for stabilizing Lycra.

The change in resistance versus speed and temperature on the weft side of the fabric is shown in Figure 4:

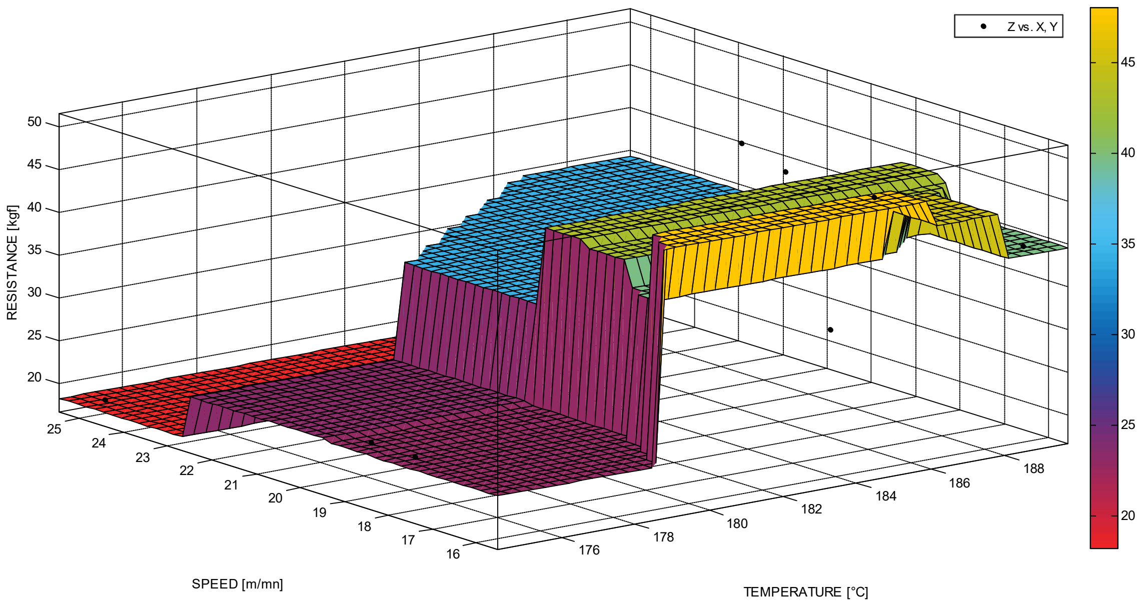

Fig. 4. Fabric weft strength

The resistance decreases in frame. This decrease is very remarkable if we keep the speed constant and vary the temperature. With a high temperature and a short residence time there is a degradation of the fabric due to the temperature. It should be noted that we took 50 Kgf as the peak value of the resistance.

4.2.2 Standard heat setting equation for strength

Equation 4 illustrates the evolution of the chain resistance of the tissue which is a function of temperature and speed:

$$R_c(x,y) = 49{,}26 + 3{,}06\sin(2{,}66xy) + 1{,}45e^{-(1{,}85y)^2} \quad (4)$$

- R: Resistance in [Kgf]
- x : Temperature in [°C]
- y : Speed [m/mn]

This equation has an absolute error of ΔR= 2,5 Kgf with a relative error $\frac{\Delta R}{R} = 5{,}53\ \%$

The evolution of the weft resistance of the fabric which is a function of temperature and speed is defined by the relation (5):

$$R_w(x,y) = 35{,}33 - 1{,}22\sin(2{,}07xy) + 0{,}46e^{-(0{,}44y)^2} \quad (5)$$

The precision of this equation is defined by the error values below:

- Absolute error: ΔR= 5,09 Kgf
- Relative error: $\frac{\Delta R}{R} = 16{,}21\ \%$

4.3 Results in relation to the initiated tear of the tissue

4.3.1 Influence of temperature and speed on the initiated tearing of the fabric

In parallel with the resistance of the fabrics, a study on the behavior of the initiated tear of the fabric was carried out. Furthermore, it is almost constant along the warp of the fabric, so we focused on the weft part. Figure 5 represents the evolution of the tear initiated in the weft of the fabric which is a function of the temperature and the speed of the expander reams:

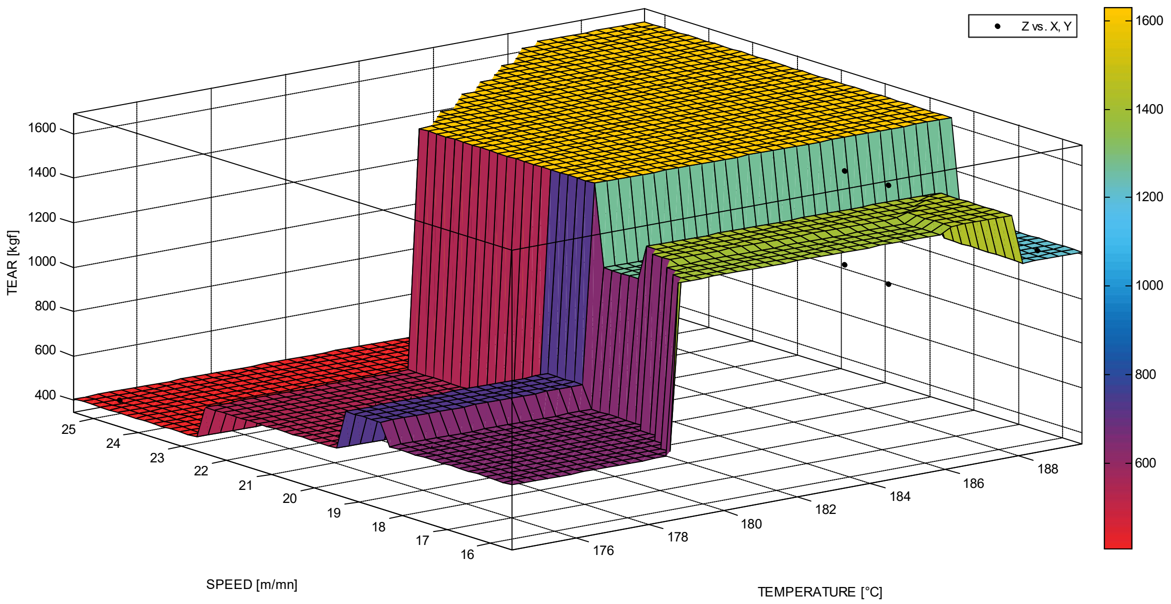

Fig. 5. Evolution of the initiated tear

The initiated tearing decreases in weft, especially at low temperatures. It should be noted that we took a peak value of 1631 Kgf for the initiated tear. According to the evolution of our curve, this value is reached when the temperatures of the widening train compartments go beyond 185°C and the speed exceeds 20 m/min.

4.3.2 Standard Thermo-setting equation for initiated tear

The evolution of the initiated tear as a function of the speed and temperature of thermo-setting of the fabric is illustrated in equation 6 :

$$T(x,y) = 0{,}48 - 0{,}88\sin(1{,}70xy) + 0{,}93e^{-(0{,}11y)^2} \quad (6)$$

- T: Tearing started in [Kgf]
- x : Temperature in [°C]
- y : Speed [m/mn]

The reliability of this equation is defined by error parameters namely:

- Absolute error: ΔT= 224 KgF
- Relative error: $\frac{\Delta T}{T} = 13{,}13\ \%$

4.4 Results in relation to tissue elasticity

4.4.1 Influence of temperature and speed on the elasticity of the fabric

Elasticity tests were carried out during our study, which were carried out on a Hounsfield H5KS THE testing machine. Figure 6 represents the evolution of the elasticity of the fabric after heat setting as a function of the speed and temperature of the expander reams during treatment:

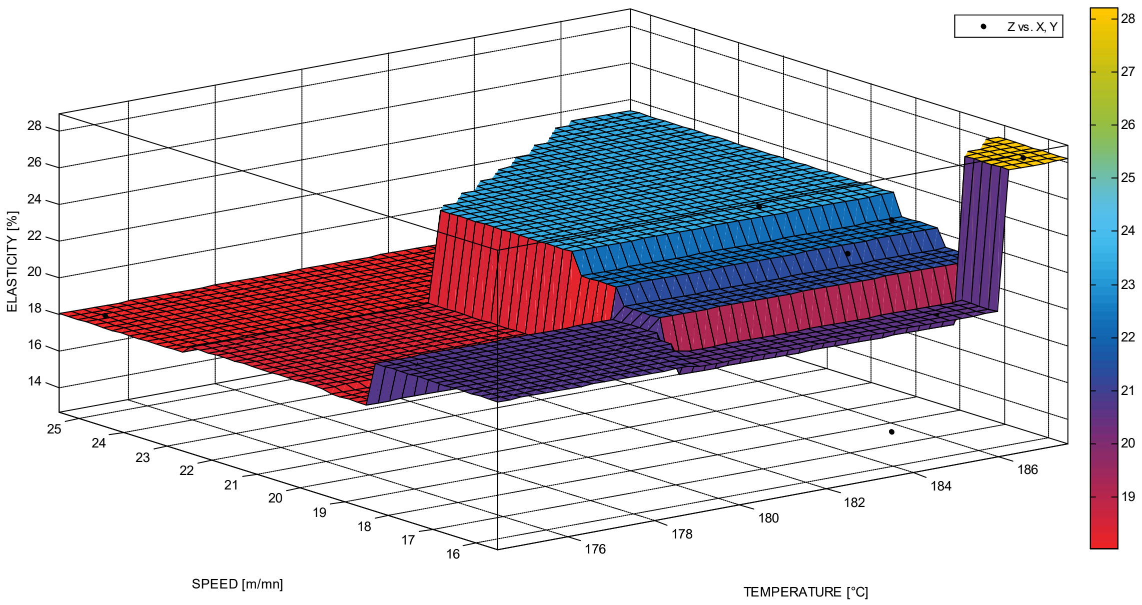

Fig. 6. Evolution of fabric elasticity

We notice that the elasticity is rising when the speed is increased. This increase is due to the residence time in the machine. However, if we consider the speed of 17 m/min, we see a particularly low value of elasticity, which is due to the change in temperature and the stretching of the fabric during the tests carried out, but in general we can say that the elasticity increases as temperature increases.

4.4.2 Standard heat setting equation for elasticity

To have a better appreciation of the elasticity upstream of the heat setting treatment, a standardization equation is proposed during our study. The equation of elasticity which is a function of temperature and speed is presented by equation 7:

$$E(x,y) = 21{,}8 - 0{,}69\sin(0{,}11xy) + 0{,}06e^{-(0{,}44y)^2} \quad (7)$$

- E: Elasticity in [%]
- x : Temperature in [°C]
- y : Speed [m/mn]

The precision of this equation is defined by the errors below:

- Absolute error: ΔE = 3,81%
- Relative error: $\frac{\Delta E}{E} = 15{,}3\ \%$

4.5 Results compared to fabric width

4.5.1 Influence of temperature and speed on the width

The useful width of the fabrics is an essential parameter that must be respected. During our study we evaluated the impact of heat setting on the width of the fabric. Figure 7 illustrates the evolution of the width as a function of temperature and processing speed during heat setting:

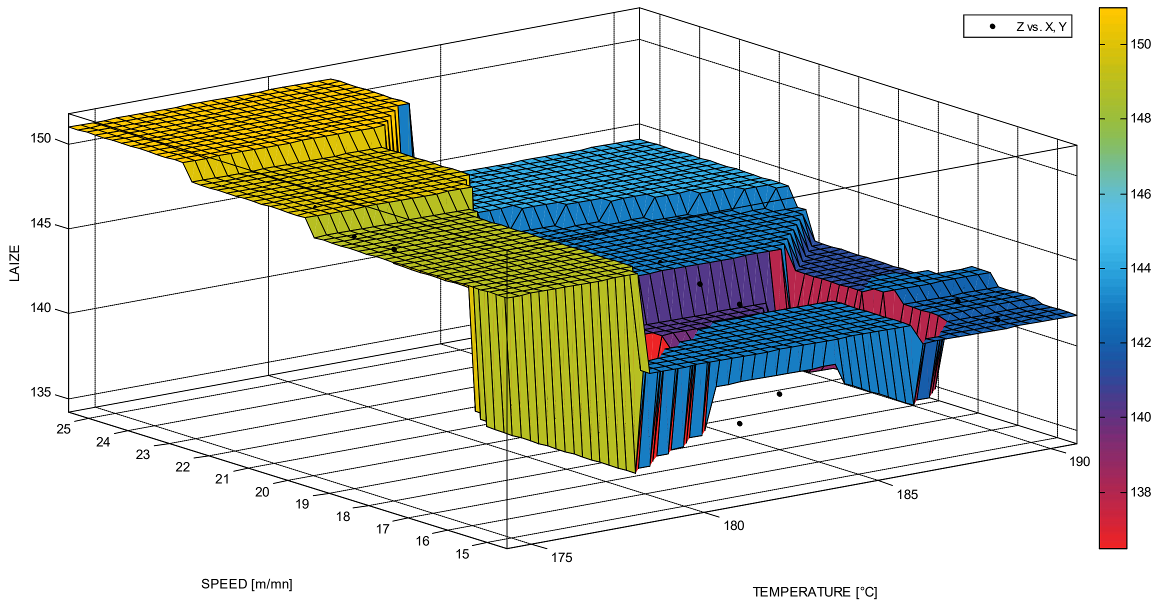

Fig. 7. Evolution of the width of the fabric

If we put the fabric under 185°C with a speed above 20 m/min and we have a width before thermo of 160 (-12/-13) we will have after thermo a width of 157 (-9.8 /-8.3). With this process we obtain a useful width of 153 and a shrinkage of 0 to -5. Here we are still out of tolerance. It would be interesting to have a width of 150 and a shrinkage of 0 to -5 in warp and weft. To achieve this, we must repeat the heat-fixing process of the fabric which involves a change in shade but also impacts the resistance of the fabric..

4.5.2 Standard heat setting equation for width

In order to have the best adjustment parameter as far as for having a width that follows the standards in terms of dimension and shrinkage, we propose the standardization equation which is a function of temperature and speed:

$$L(x,y) = 142{,}3 + 0{,}06\sin(2{,}62xy) + 0{,}18e^{-(0{,}35y)^2} \qquad (8)$$

- L: width in [cm]
- x : Temperature in [°C]
- y : Speed [m/mn]

The precision of this equation is defined by the error values, namely:

- Absolute error: $\Delta L = 0{,}65$ Cm
- Relative error: $\frac{\Delta L}{L} = 0{,}45\ \%$

V. Conclusion and perspectives

This article proposes standard equations for the parameterization of expander frames such as the appropriate temperature and speed during the thermo-setting process of a fabric containing less than 3% elastanes. Knowing that the objective when producing a fabric is to have a fabric that meets the customer's requirements, our study contributes to the choice of optimal parameters for the treatment of fabrics in order to have one fabric at a time stable and durable. Note that the standardization study took into account several parameters linked to stability and resistance such as elasticity, initiated tearing and the useful width of the fabric. For each physical test considered, a standard equation has been proposed.

As a perspective, a study based on the impact of wire characteristics on physical control parameters of tissues 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.