STUDY REGARDING THE LEATHER SUBSTITUTES BEHAVIOR ON TENSILE STRESS

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Abstract: The lasting process of the footwear uppers implies mainly a tension stress that creates elongations in the material's structure. The forming capacity of the leather substitutes can be appreciated through the proportion of the plastic elongation compared to the total elongation. The elongation value is influenced by a series of technological parameters as well as by the structure of the material. This paper presents some mathematical models that illustrate the relationship between stress and elongation on constant speed of tension, as well as the dependence of the total elongation with tension speed at constant stress.

1. INTRODUCTION

The manufacturing of footwear implies the use of a large scale of leather substitutes for uppers whose properties are directly involved in the quality of the shoe. The mechanic properties of leather substitutes that are considered elasto-plastic materials are most influenced by their structure.

During lasting process of the footwear with uppers from leather substitutes on textile layer, the elongation due to tension stress is influenced by the type of the textile layer used and by other technological parameters, such as speed and tensile time.

The uppers are strain to get the complex shape of the last and would have to retain it after last has been removed from the finite product. There for, it is necessary that an important part from total elongation to transform into plastic elongation in order to assure stability of the shoe shape during lasting.

2. EXPERIMENTS

There had been used two leather substitutes of same thickness (1,2mm), but different as for the support:

- ✓ Leather substitute, with polyurethane layer of shiny type on textile support (IP1)
- ✓ Leather substitute, with polyurethane layer of velvet pattern on textile support (IP2).

The test samples, maintained for a period of 24h at a temperature of 20±2°C and the relative humidity of air of φ=65±5% were subject to tension stress in the following conditions:

- tensile effort: σ=0,5, 0,75 and 1 daN/mm^2;
- deformation speed: v=50, 100, 150 mm/minute;
- length of sample between clamps: l=100mm;

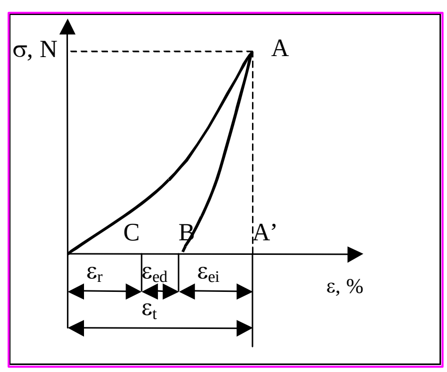


Figure 1.The total and plastic elongation

- number of parallel determinations: n=5.

The geometric relation between the deformations is given by graphic from figure 1:

$$\varepsilon_t = \varepsilon_{ei} + \varepsilon_{ed} + \varepsilon_r = \varepsilon_e + \varepsilon_r \qquad (1)$$

There has been registered the total elongation for certain tensile stress and solicitation speed. The values of total elongation and those of its components, elastic and plastic, are mentioned in table 1.

Table 1.Mean values for total elongation**(**ε_t), plastic elongation(ε_t) and elastic elongation(ε_e)

Nr. crt.	Speed mm/min.	Tensile effort σ daN/mm²	Leather substitute-**IP 1**			Leathear substitute-**IP 2**		
			ε_t, %	ε_e, %	ε_r, , %	ε_t, %	ε_e, %	ε_r, , %
1.	50	0.5	11.6	10.4	1.2	8.3	7.3	1
2.		0.75	13.6	11.8	1.8	10.6	9.4	1.2
3.		1	14.8	11.4	3.4	13	11.2	1.8
4.	100	0.5	10.8	9.2	1.6	7.8	6.8	1
5.		0.75	13.2	11.6	1.6	10	8.8	1.2
6.		1	14	11.7	2.3	12.3	10.5	1.8
7.	150	0.5	10	8.4	1.6	6.8	5.6	1.2
8.		0.75	12.6	10.8	1.8	9.6	8	1.6
9.		1	13.6	11.3	2.3	11	9.4	1.6

In order to grow the plastic elongation of leather substitutes and the capacity to retain shape after the tensile stress is off there had been done tests resulting an elongation of 10%, samples being submitted to a fixing thermal treatment. Thus there had been taken into consideration the following parameters:

- Treatment time: 1minute, 7 and 13minutes;
- Temperature: 100°C and 140°C.

During the fixing thermal treatment tensional samples have been kept at normal temperature for 180minutes.Table 2 presents the variation of plastic elongation depending on the fixing thermal treatment to which samples have been submitted on stress conditions and also on the time elapsed since the stress has been interrupted (1/2h, 24h, 48h and 72h).

Table 2. Mean values for plastic elongation as function of thermo-fixing treatment

Thermo-fixing treatment		Plastic elongation ε_r [%]			
Temperature, ◦C	Time, minutes	½ hour	24 hours	48 hours	72 hours
100	1	5.52	4.92	4.55	4.20
	7	6.43	5.8	5.18	4.80
	13	6.98	6.35	5.74	5.17
140	1	6.31	5.60	5.23	4.35
	7	6.73	6.11	5.87	5.06
	13	7.28	6.61	6.25	5.42

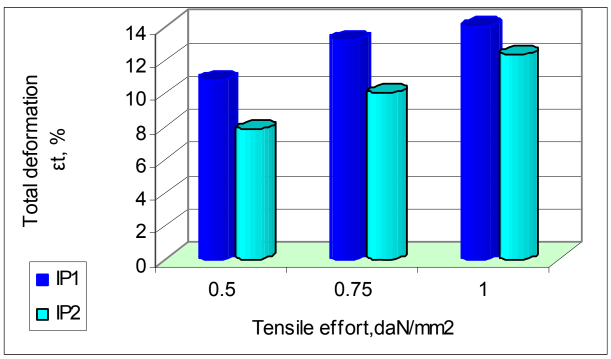
Excel and graphic representation had been used to evaluate the experimental data.

3. RESULTS AND INTERPRETATIONS

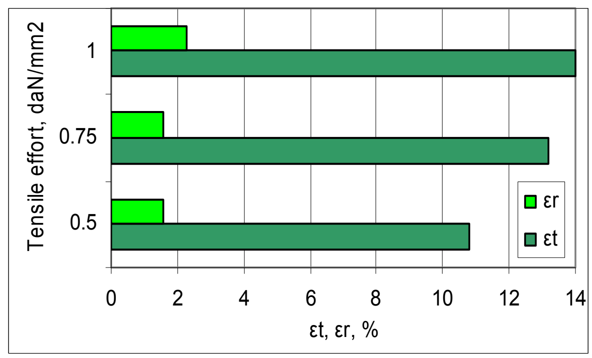
The deformability of the experimental substitutes on textile layer, that one has a velvet pattern and other one, has a polyurethane shine surface, is varying with tensile stress (0,5, 0,75 and 1 daN/mm^2) and different solicitation speeds (50, 100, 150 mm/minute).

The variation of total elongation depending on the solicitation effort for a constant value of solicitation speed, 100mm/min, is shown in figure 2a.

Substitute type has a total elongation higher than, plastic elongation representing only 1,6% from whole elongation of 13,2% considered for a medium tensile effort of 0,75 daN/mm^2, figure 2b.



a)



b)

Figure 2: a)The dependence of total elongation with tensile effort for a particular speed of solicitation v=100mm/min.
b)The relationship between plastic(ε_r) and total elongation for IP2 leather substitute

The total elongation is increasing with tensile stress, on constant speed and it is decreasing with solicitation speed for a particular constant value of the tensile effort. The dependence of total elongation with solicitation speed (figure 3- velvet pattern substitute) is described by linear regression models as:

$$y=-ax+b \qquad (2)$$

Where:

y –total elongation, %;

x- solicitation speed, mm/minute;

a– coefficient for regression equation.

b-constant for regression equation

Mathematical models resulted after evaluating the experimental data are presented in table 3.

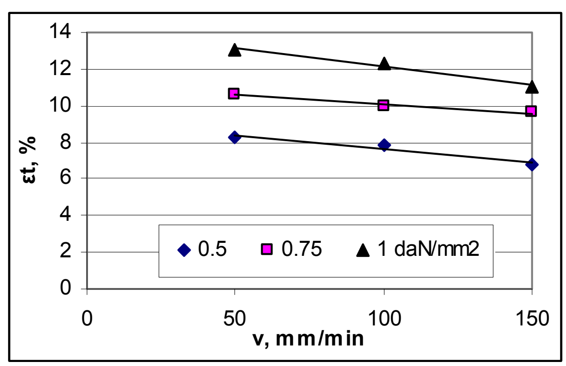


Figure 3. The dependence of total elongation with solicitation speed, v, for different tensile efforts: 0,5, 0,75 and 1 daN/mm^2

The relationship between tensile stress and elongation on 100 mm/ min.

speed is illustrated by figure 4.
One could observe that the relation is not proportional; hereby the Hooke law is not respected.

Table 3.The regression models for different tensile efforts

Substitute type	Effort daN/mm^2	*Reggresion model*	Coefficient R^2
IP 1 Shiny type	0.5	y= -0.016x+12.333	0.9796
	0.75	y= -0.01x+14.133	0.9868
	1	y= - 0.012x +15.333	0.9643
IP 2 Velvet type	0.5	y= - 0.015x + 9.133	0.9643
	0.75	y= - 0.020x + 11.867	0.9868
	1	y= - 0.02x +14.100	0.9701

The deformability of the materials used for experiments follows a power regression equation as:

$$y=ax^b \qquad (3)$$

Where: y- the dependent variable (tensile stress, σ), in N/ mm^2;
x- independent variable (total elongation, ε), in %. Other related equations could be:

$$\sigma=a\varepsilon^b \qquad (4)$$

$$\sqrt[b]{\sigma}=a\varepsilon \qquad (5)$$

$$\sigma^{\frac{1}{b}}=a\varepsilon \qquad (6)$$

$$\varepsilon=\frac{\sigma^{\frac{1}{b}}}{a} \qquad (7)$$

Table 4 illustrates the relationship between total elongation and tensile effort corresponding to a certain value of solicitation speed for linear regression models.

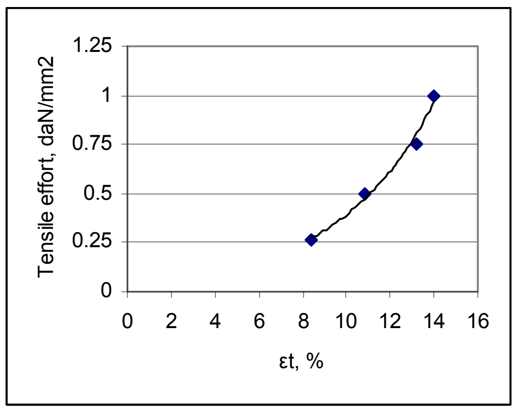


Figure 4. Total deformation as function of tensile effort for IP1 substitute

Table 4.Regression models for different solicitation speeds

Substitute type	Speed mm/min	***Reggresion model***	Coefficient R^2
IP 1 Shiny type	50	$y=0.0004x^{2.8738}$	0.9985
	100	$y=0.0008x^{2.6778}$	0.9817
	150	$y=0.0011x^{2.5876}$	0.9783
IP 2 Velvet type	50	$y=0.0083x^{1.888}$	0.9832
	100	$y=0.0105x^{1.8404}$	0.9853
	150	$y=0.021x^{1.6071}$	0.9875

The fixing thermal treatment is required by the necessity of increasing both the permanent deformation of the substitutes and the capacity to keep the shape after the stress has been interrupted.

Figure 5 presents the variation of the permanent elongation as function of the fixing thermal treatment (treatment time: 7 minutes; temperature: 100°C and 140°C) and as function of the measuring time after the sample has been tested.

The permanent deformation (elongation) increases with time and temperature. Its value at 48 hours after solicitation grows up from 0.69% to 5.18 %, for T=100°C and to 5.87, for T=140, in 7 minutes.

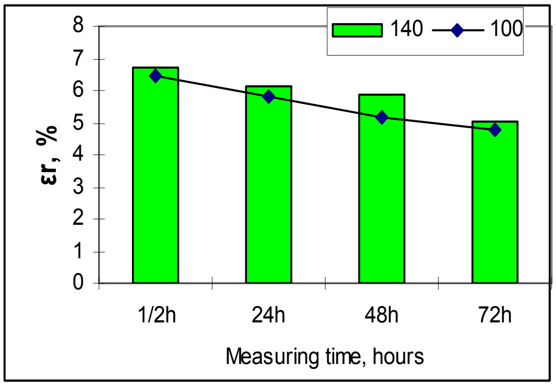


Figure 5. ***The dependence of the plastic elongation function on measuring time (½, 24, 48 and 72 hours) for three thermo-fixingreatment times (time 7 minutes)***

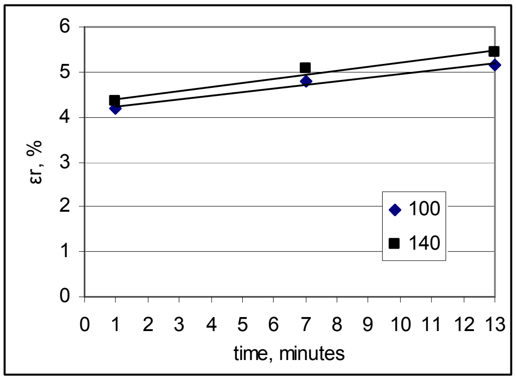


Figure 6.The plastic elongation as function on fixing thermal treatment time

Figure 6 shows the variation of plastic elongation depending on the fixing thermal treatment time. The values have been calculated for a relaxing time of 72 hours (the time between stress release and elongations measurements).

It results that the dependence of plastic elongation with treatment time, for different values of thermal fixing temperature, is made obvious through regression models (table 5), linear type, functions being given by general expression:

$$\varepsilon_r=ct+d \qquad (8)$$

Table 5.Regression models as to illustrate the dependence of elongation with treatment time

Temperature, ˚C	***time, hours***	***Regression model***	***Coefficient R^2***
100	1/2	ϵ_r=0.1114t +5.4932	0.9659
	24	ϵ_r=0.1618t +5.277	0.9427
	48	ϵ_r=0.0912t +4.4877	0.9939
	72	ϵ_r=0.074t +4.1806	0.9678
140	1/2	ϵ_r=0.0747t +6.2254	0.9989
	24	ϵ_r=0.1192t +4.8558	0.9826
	48	ϵ_r=0.085t +5.1883	0.9788
	72	ϵ_r=0.0892t +4.3192	0.9656

The coefficient and the constant for regression equation (8) depend on fixing thermal treatment time and temperature and also of the measuring time for plastic elongation.

4. CONCLUSION

The regression models that illustrate the relation between stress and elongation are nonlinear, power type, and estimation function is given by general equation $\sigma=a\varepsilon^b$; the deformability of tested materials is given by a modified equation:

$$\varepsilon = \frac{\sigma^{\frac{1}{b}}}{a}.$$

The dependence of the total deformation upon solicitation speed follows linear models:

$$\varepsilon_t = -av+b.$$

The negative sign from regression equation gives a down proportional variation of the total deformation as function of solicitation speed.

The permanent deformation is depending on fixing thermal treatment time, for different values of the temperature, after a linear model:

$$\varepsilon_r = ct+d.$$

For practical conditions, a treatment that does not influence the work productivity and in mean time allows a good dimensional stability by reducing elastic deformation and increasing permanent deformation will be adopted.

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