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TENSILE STRENGHT OF COMPOSITE MATERIALS DURING THE LASTING PROCESS

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Abstract: *The manufacture of footwear suppose tensile loads during the lasting process of uppers. The paper presents the results of the study for the materials' behavior under tensile stress. To this intent, the breaking strength and elongation at break have been analyzed when the tensile load of 10N/mm^2 is applied to flexible materials and leather. The behavior under the tensile stress of 10N/mm^2, tested in order to determine the materials deformability during the lasting process, has been observed using tensile testing machine SATRA (STM 466) and its software providing quick and simple-to-understand load-distance graphics. The elongation corresponding to a tensile stress of 10N/mm^2, concluded from the graphics, is useful for characterizing the mechanical properties of materials as the lasting process involves stresses of about 7-8 N/mm^2. It was found that the selected materials for the present study can be used for sport footwear manufacture combined with leather and spacer fabrics. In the case of composite materials, the elongation at break is smaller than for the simple materials, tested individually. Among leathers, the biggest values of the maximum tensile force at breaking were obtained for nubuck leather, followed by box calf leather.*

Key words: *tensile, breaking, strength, elongation, leather, spacer fabric*

1. INTRODUCTION

In the lasting process of sports footwear, the shoe uppers are tensioned so that their shape is maintained after removal of the last from the finished product and particularly during wear [1, 2, 3]. The lasting process implies a tensile load applied to materials that is mostly achieved by creating a residual elongation in the structure of the material [4]. In order to obtain a spatial form as stable as possible in behavior, it is necessary that a greater part of the total elongation is transformed into plastic elongation [5, 6].

Flexible materials behavior, in the case of manufacture and wear of the sport footwear is established following a series of mechanical characteristics such as:

~ *elongation at imposed tensile load (1 daN/mm^2),* ε_i, highlights the leather and leather substitutes' capacity to change shape in the lasting process, in the case of machines that work with loads close to this value;

~ *elongation at break*, respectively the elongation when the breaking takes place;

Starting from these aspects, the paper presents the results of tests at breaking of some flexible materials: leather and textile composites used for footwear uppers [7].

2. EXPERIMENTAL PART

The behaviour of the flexible materials has been observed with the help of testing machine SATRA (STM 466) with 466F attachment, and SATRA software, providing quick results and statistical analysis**,** figure 1.

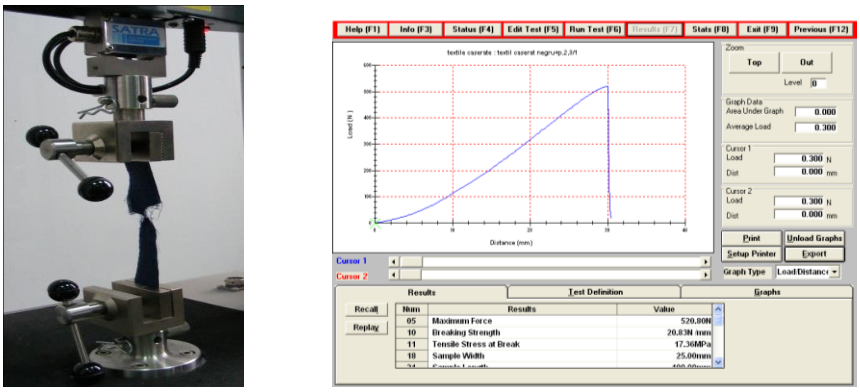
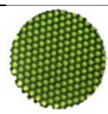


Fig.1 *Tensile testing and load distance graph at breaking*

The tests have been done with materials usually used for manufacturing sport footwear uppers, both leather and composite textiles like warp-knitted spacer fabrics, table 1.

The spacer fabrics are three dimensional kintted fabrics consisting of two separate knitted layers which are joined together by spacer yarns. The spacer fabrics tested in this paper have a monofilament spacer layer.

Table 1. *Materials used for testing*

Nr.	Code	Material	δ /mm/	Photo sample	Nr.	Code	Material	δ /mm/	Photo sample
1.	P1	Box calf leather	1.3		4.	TS1	Spacer fabric 1	3.2	
2.	P2	Nubuck leather	1.4		5.	TS2	Spacer fabric 2	3.0	
3.	P3	Nappa leather	0.9		6.	TS3	Spacer fabric 3	2.3	

The specimens have been cut at dimensions specified in SR EN ISO 3376/2003: total length l=190mm; length betwwen clamps l_0=100, width b=20mm. After conditioning (as provided in the ISO2419 standard) the specimens were tensioned at Satra dynamometer until breaking at a speed of 100±5 mm/minute. The software of the dynamometer allowed registering of load-distance graphs as the tensile testing was performed.

3. RESULTS AND DISCUSSIONS

After testing the materials till breaking off, the software of the dynamometer SATRA STM 466 has registered for each specimen the load-distance graphic, as well as the peak force (N) –the highest value registered throughout the testing, the force at breaking (N) – registered when the specimen breaks, the breaking strength in N/mm^2, tensile elongation (%) – elongation of the sample under tensile stress, the elongation at break (%) and the longitudinal elastic modulus, in N/mm^2.

The specimens shape and dimensions were cut as provided by the SR EN ISO 2418/2003. Before testing, the specimens were conditioned under standard conditions (SR EN ISO 2419/2006) of 20±2°C and 65±2% humidity for 24 hours.

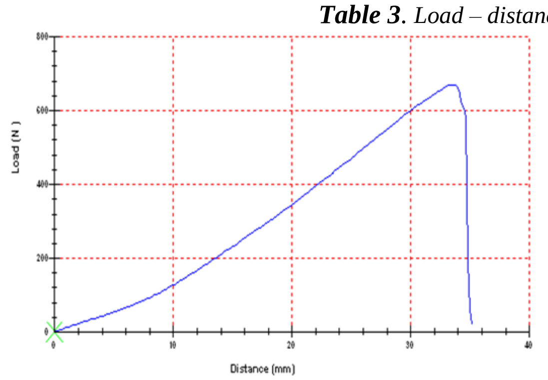
As an example, there are presented the medium values for breaking strength and elongation at break for nubuck and spacer fabric, table 2.

Table 2. *Simple materials and combined(composite) materials*

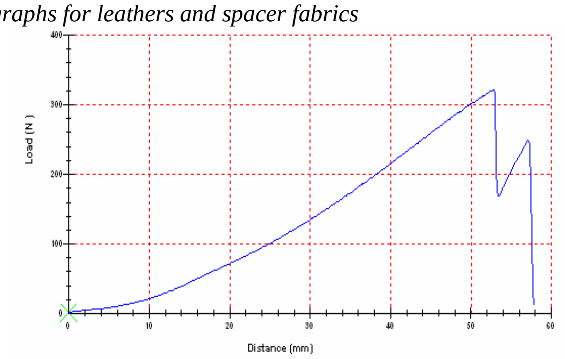
Nr. crt.	Specimen type	Code	F_{max} [N]	F_{rup} [N]	Force at breaking the first layer [N/mm]	R_{rup} [N/mm^2]	Rmax [N/mm^2]	ε [%]	E [N/mm^2]
1.	Nubuck	A3»	558.367	475.167	27.562	21.598	25.380	33.050	94.625
2.	Spacer fabric	D6	412.267	253.46	5.51	8.962	86.850	17.801	412.267
3.	Nubuck + Spacer fabric	A3D6	678.900	678.900	33.953	9.174	9.174	75.492	23.44

All graphs registered for the materials tested at *SATRA (STM 466), with STM 466F attachment*, are illustrated in table 3.

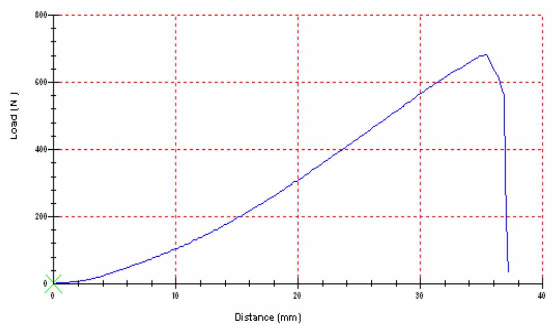
Table 3. *Load – distance graphs for leathers and spacer fabrics*

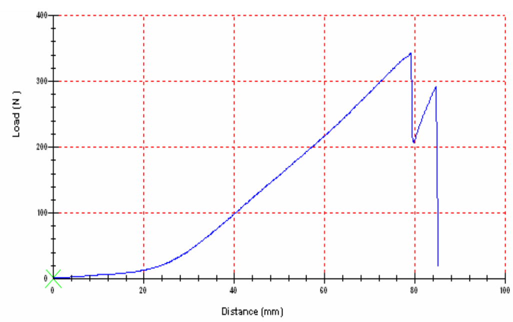


P1

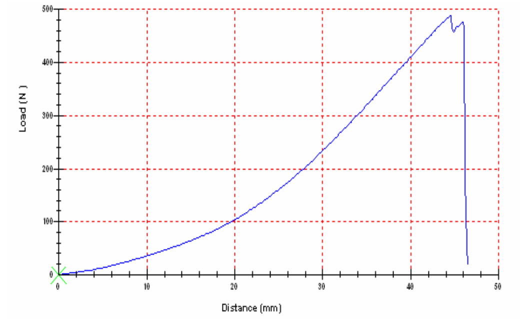


TS1

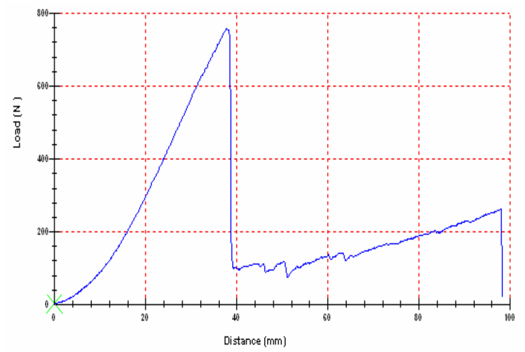




P2

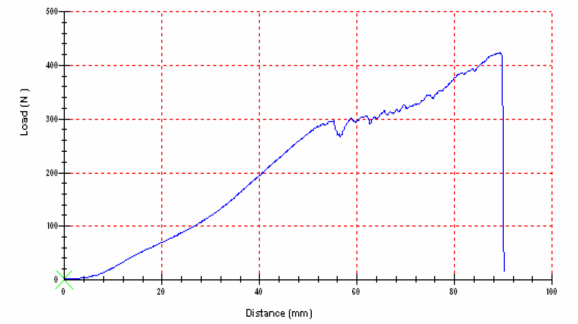


P3

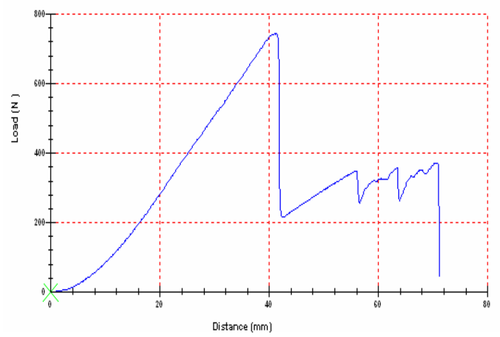


P3TS2

TS2



TS3



P2TS3

The load-distance graphs that allow obtaining the elongation at an imposed value of 10N/mm^2, resulted a value of 17.2% for the box calf leather P1. In the case of an imposed tensile load of 10 N/mm^2, the elongation is 18,5% for nubuck , and 26.5% for the nappa leathers.

In the case of the tested leathers, the obtained values for the elongation corresponding to a load of 10N/mm^2 are situated in the limits provided by the actual standars, respectively between 18-28%. As seen in the graphs, the maximum values of the peak force were obtained for nubuck (P2), followed by the box calf leather (P1). Concerning the breaking strength the spacer fabrics have smaller values than for the leathers, figure 2.

The breaking strength corresponding to the first cracking point of the fabric is smaller than the maximum strength obtained during the entire tensile testing. The spacer fabric TS3 resists only at a value of 7N/mm^2. Spacer fabrics TS1 and TS2 present a smaller strength during the lasting process. Thus, in order to resist throughtout the lasting process of the uppers, these materials must be reinforced in the areas of maximum tensioning.

The elongation at break is comprised between 40-78% for spacer fabrics and 32-42% for leathers used in the manufacture of footwear uppers, figure 3.

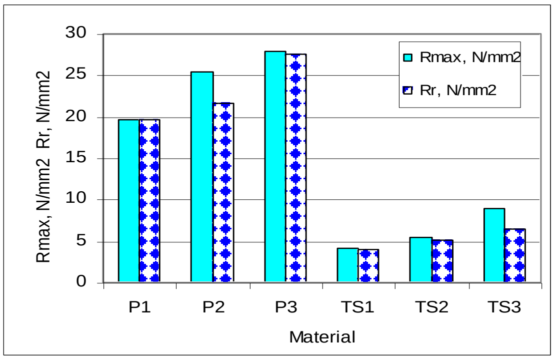


Fig.2. *The breaking strength for leathers and spacer fabrics*

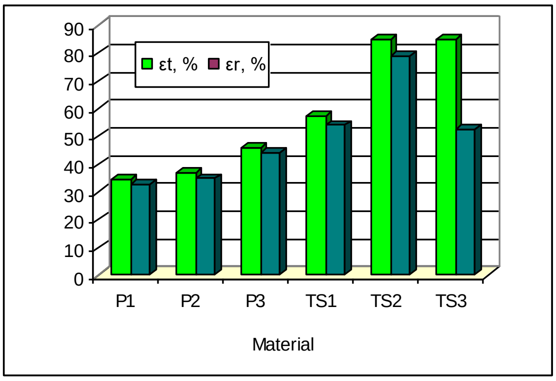
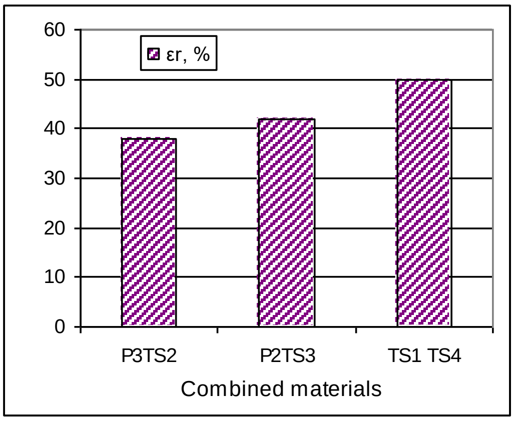
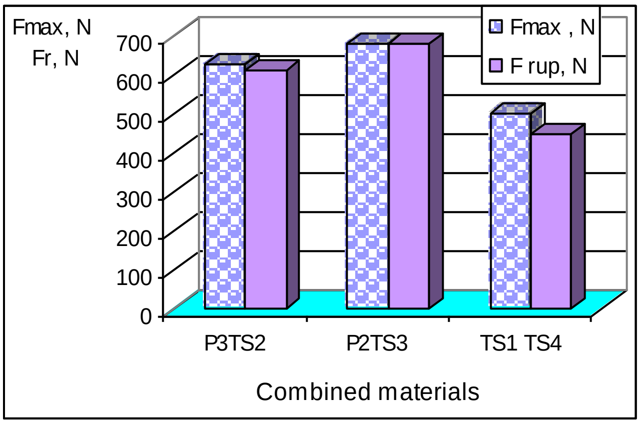


Fig.3 *Elongation at break*

These fabrics break at forces far bellow those corresponding to an imposed load of 10N/mm^2.

In the case of composite materials, the elongation at break is smaller for the structures of materials than for the simple materials, figure 4a. Instead, small differences between the peak force and the force at breaking are noted, figure 4b.





b)

Fig.4. *Elongation at break (b) and force at breaking (a) for the combined materials*

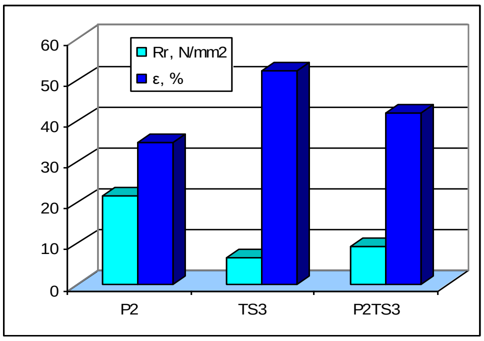


Fig.5. *Elongation at break and breaking strength for simple and combined materials*

From the tested composite materials, P2TS3 (nubuck with spacer fabric) presents the highest value of the force at breaking, the strength being of 9,2 N/mm^2. Thus this structure of combined materials will resist during the lasting process.

Elongation at break and breaking strength for the structure of materials P2TS3 are illustrated in figure 5, comparatively with values registered for the component materails (leather and spacer fabric), tested individually.

4. CONCLUSIONS

In the case of tested materials several results emerge:

- ✓ The load-distance graphs from the Satra dynamometer offer useful information as fot the breaking of materials.
- ✓ Among the tested leathers, the biggest values of the maximum tensile force were obtained for P2 leather (nubuck), followed by P1 leather (box calf), respectively values of breaking strength between 20 şi 28N/mm^2.
- ✓ The spacer fabrics present a strength of the first breaking smaller than the maximum tensile strength, respectively values between 3.80 and 11N/mm^2.
- ✓ The spacer fabric TS3 resists only at a load of 7N/mm^2. Spacer fabrics TS1, TS2 present a small tensile strength during the lasting process, so these fabrics cannot be used individually , a reinforcement with leather must be done in the forepart, heel or sideways.
- ✓ As for the composite materials, P2 TS3 (nubuck spacer fabric) presents the highest value of breaking strength, respectively 9,2N/mm^2. So, this combination of materials will resist in the lasting process of uppers. The structure of materials P3TS2 will resist at a tensile load of 7N/mm^2.
- ✓ The maximum elongation at break, for the combination of materials (leather and spacer fabric), present bigger values than the elongation corresponding to the break of the inferior layer of the material.
- ✓ The load – distance graphs registered at Satra dynamometer determine the elongation at an imposed tensile load of 10N/mm^2, in order to highlight the deformation capacity during lasting process (knowing that the tensile loads at uppers lasting are of 7-8 N/mm^2).
- ✓ In the case of the tested leathers, the values of elongation obtained under a tensile stress of 10 N/mm^2 are within the limits set by the standards, ie between 18-28%.

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