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CONSTRUCŢII DE MAŞINI

METHOD FOR EVALUATION THE MECHANICAL PROPERTIES OF SOME MATERIALS BASED ON SOME HYSTERETIC CURVES

BY

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Abstract. The production of new protective equipment, with superior properties to those existing on the market at the moment, can be done by using new materials, with superior mechanical characteristics (Shishoo, 1995). In order to evaluate these characteristics, it is necessary to develop a methodology and use adequate experimental installations, which allow to obtain conclusive results, based on which a series of conclusions can be drawn regarding the possibilities of using these materials.

This paper presents an installation and a test method for evaluating the mechanical properties of some materials.

Keywords: loading force; testing machine; hysteretic curve.

1. Introduction

The rapid increase in the volume of industrial activities in all fields has led to the need to find solutions for better protection of human operators The rapid increase in the volume of industrial activities in all fields has led to the need to find solutions for better protection of human operators (Ziegenfuß and

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Klein, 2000; Scott, 2005; Roshan, 2019). In order to achieve this goal, research was started which led to the obtaining of new materials, with compositions and structures different from those used so far and which due to the superior mechanical properties and based on a combination chosen correctly (base material, intermediate material or filling and facade material) to lead to the obtaining of much better protective equipment (Shishoo, 1995).

In this paper we tried to test some materials and some combinations of materials, following their behavior at tests in identical conditions (strength, speed, etc.), the parameters followed (Wang *et al.*, 2008) being mainly the elasticity of materials (by relative elongation or absolute elongation), as well as the breaking limit.

2. Experimental Method

Formally, in the experiments performed, the materials were coded as follows:

- Basic material 1 - MBV1;
- Basic material 2 - MBV2;
- Basic material 3 - MBV3;
- Filling material 1 - MUV1;
- Filling material 2 - MUV2;
- Filling material 3 - MUV3;
- Filling material 4 - MUV4;
- Filling material 5 - MUV5;
- Filling material 6 - MUV6;
- Filling material 7 - MUV7;

The programming of the experiments was performed as follows:

Stage I: Study of each individual material: MBV1, MBV2, MBV3, MUV1, MUV2, MUV3, MUV4, MUV5, MUV6, MUV7.

Stage II: Study of the characteristics of the packages obtained through the combinations of two materials:

- MBV1+MUV1; MBV2+MUV1; MBV3+MUV1;
- MBV1+MUV2; MBV2+MUV2; MBV3+MUV2;
- MBV1+MUV3; MBV2+MUV3; MBV3+MUV3;
- MBV1+MUV4; MBV2+MUV4; MBV3+MUV4;
- MBV1+MUV5; MBV2+MUV5; MBV3+MUV5;
- MBV1+MUV6; MBV2+MUV6; MBV3+MUV6;
- MBV1+MUV&; MBV2+MUV7; MBV3_MUV7.

Stage III: Study of the characteristics of the packages obtained through the combinations of three materials:

MBV1+MUV1+MBV1; MBV2+MUV1+MBV2; MBV3+MUV1+MBV3;
MBV1+MUV2+MBV1; MBV2+MUV2+MBV2; MBV3+MUV2+MBV3;

MBV1+MUV3+MBV1; MBV2+MUV3+MBV2; MBV3+MUV3+MBV3;
MBV1+MUV4+MBV1; MBV2+MUV4+MBV2; MBV3+MUV4+MBV3;
MBV1+MUV5+MBV1; MBV2+MUV5+MBV2; MBV3+MUV5+MBV3;
MBV1+MUV6+MBV1; MBV2+MUV6+MBV2; MBV3+MUV6+MBV3;
MBV1+MUV7+MBV1; MBV2+MUV7+MBV2; MBV3+MUV7+MBV3;

The study of each material and each combination of materials was performed (Hasçelik and Eren, 2016) on the machine to test materials at tension/compression **LRX Plus** (Lloyd Instruments Ltd -AMETEK-England – Fig. 1).

All tests were scheduled to take place under identical conditions (same force, same punch speed, same stress cycle, same way of fixing the material):

– Speed of movement of the punch head: 21 mm/min (made with an accuracy of 0.2%);

– Material prestressing force: 2 N;

– Tensile force of the material: 10 N;

– Punch head stroke: 10 mm.

The test of each material was made after the following cycle: prestressing with a force of 2 N, followed by 5 cycles of stress in order to reach the force of 10 N.

3. Experimental Equipment

The tests were performed on the LRX Plus tension /compression material testing machine (Lloyd Instruments Ltd -AMETEK-England – Fig. 1).

The LRX is a single column materials testing machine. The tests can be performed in various variants (stretching / compression, with one or more stress cycles, etc.). The main functional parameters are displayed on an LCD screen, and various units of measurement can be chosen. The sequential menu offered by the programming interface is simple, so that the test programming can be done quickly and efficiently. The extension measurement system uses a digital encoder to achieve high resolution throughout its extension ranges (https:// www. jlwinstruments.com).

The performances of the LRX testing machine are special also due to the software it is equipped with, which allow a very good and precise configuration of the tests but also the analysis of the obtained results. The system can be used both for batch testing in production (to perform quality controls), but can also be used for the development of high-complexity research applications (https://www.jlwinstruments.com).

Data acquisition and processing were performed using the integrated software, NEXYGEN Data Analysis, of the LRX Plus tension/compression test machine (https://www. jlwinstruments.com/products/products-library/lrx-series-materials-testing-machine/).

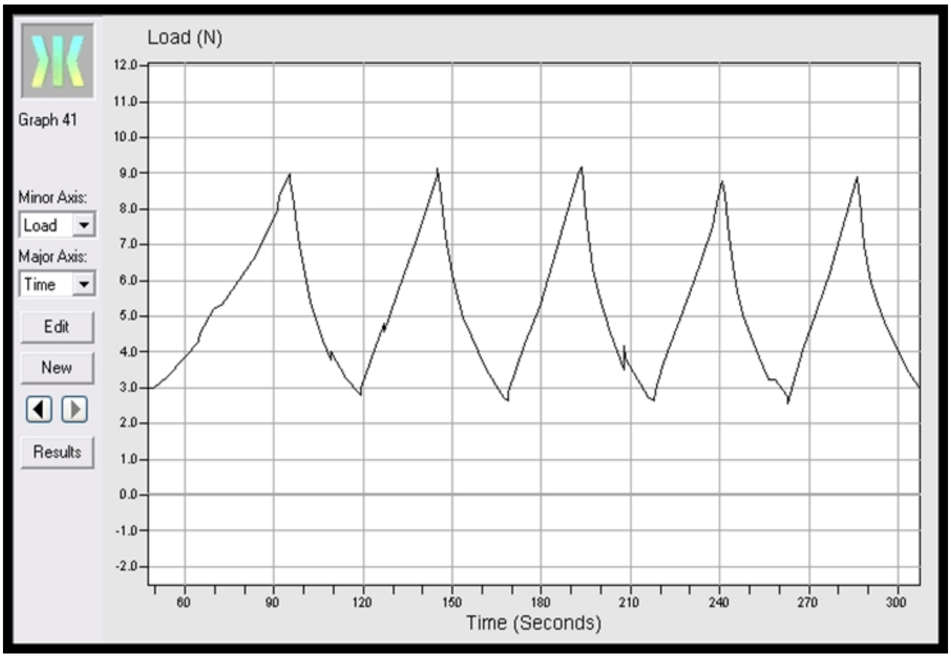
The software allows saving data in various variants (formats), so that it is possible to process and interpret them in various programming environments.

For each material the software generates the following evolutions: Load-time, Machine extension-time, Stress-time, Extension from preload-time, Percentage strain-time, Load-machine extension, Load-stress, Load-extension from preload, Load-extension strain, Stress-machine extension, Stress-percentage strain (Fig. 2).

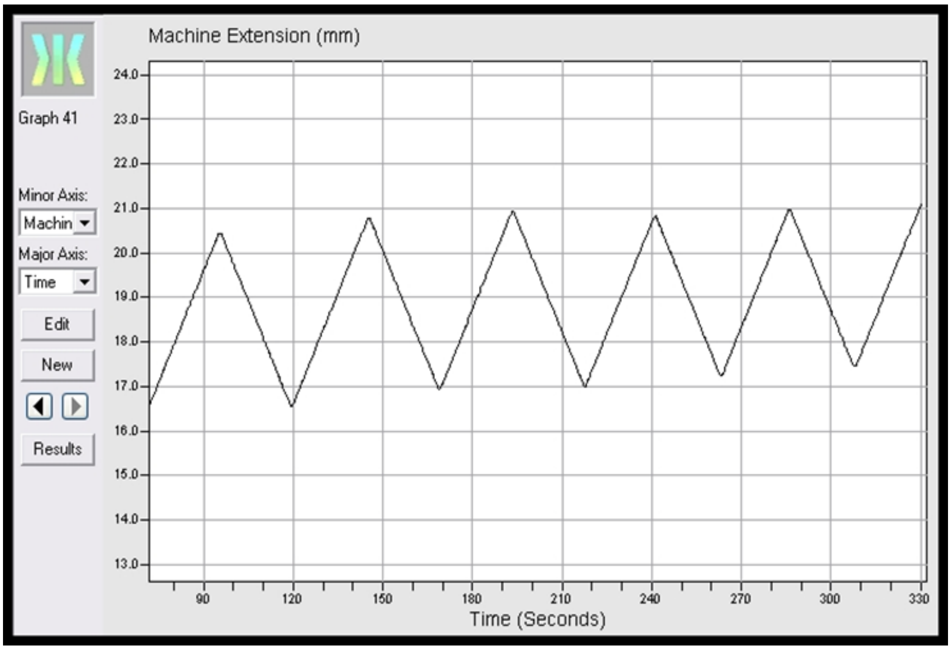
The main features of the LRX test machine are:

“-Force Range: 5kN;
-Crosshead Speed: 0.01 to 1016 mm/min;
-Speed Accuracy: < 0.2%;
-Stroke (LRX) 1 to 750 mm 0.04 to 30 inches 1 to 1500 mm;
-Load Resolution: < 5% of load cell used (max);
-Extension Resolution: < 5 microns;
-Data Sampling Rate: 40Hz;
-Extensometer Inputs: +10V dc analogue input Digital - RS232;
-Data Outputs: Digital - RS232 Analogue - 10Vdc max;
-Measuring System: Exceeds the requirements, ASTM E4, DIN 51221;
-Analysis Software: NEXYGEN™ Data Analysis Software;
-Supply Voltage: 115/230Vac ± 10% 50 - 60Hz;
-Weight: 54kg (119lb);
-Operating Temp: 5° to 35°C (40°F to 95°F)”.

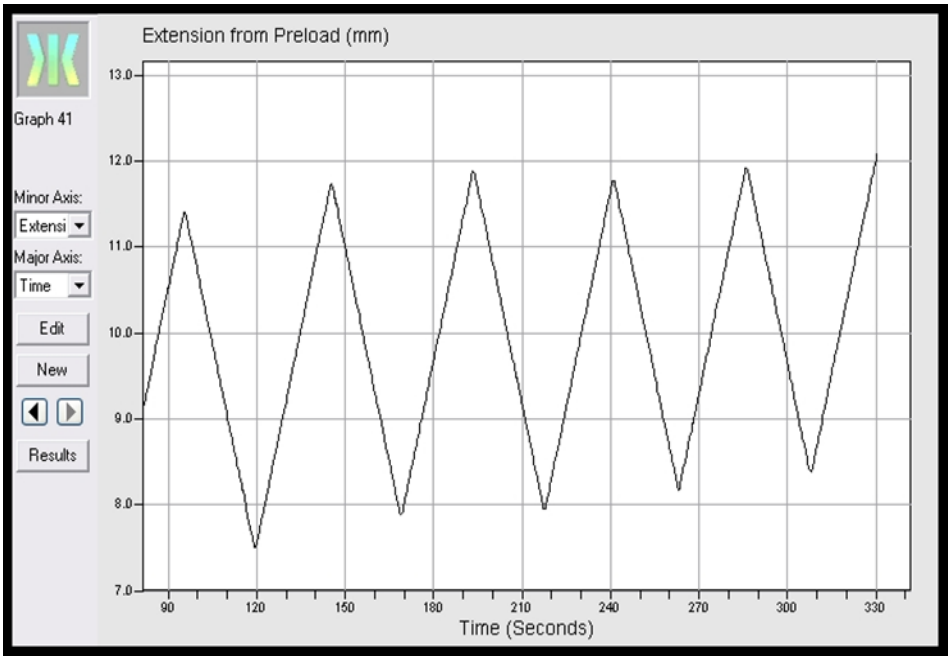
Fig. 1 – Testing machine Lloyd Instruments Ltd -AMETEK-England.


Load (N)
Graph 41
Minor Axis:
Load
Major Axis:
Time
Edit
New
Results
Time (Seconds)

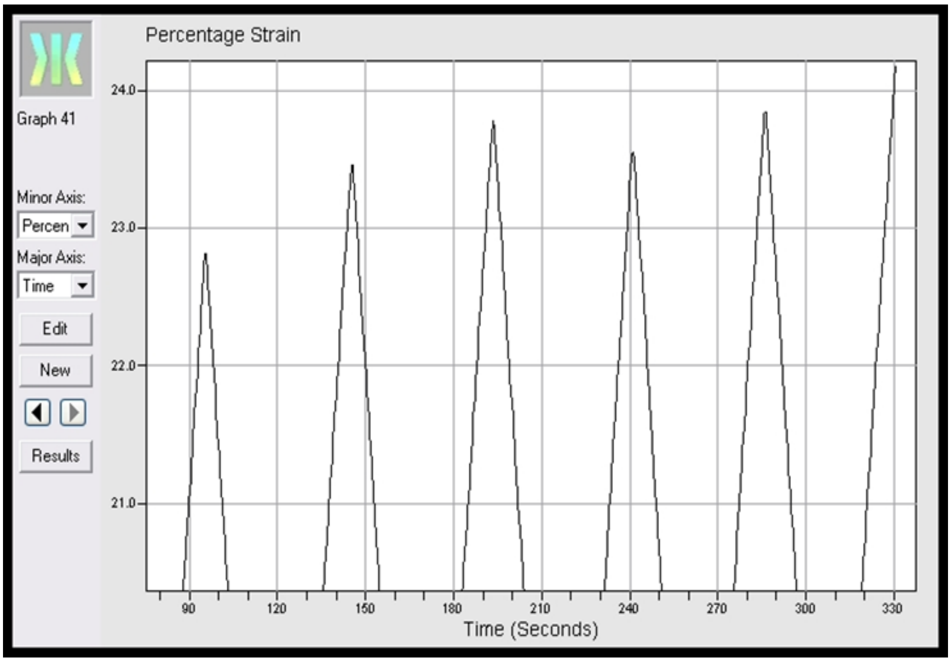
a)


Machine Extension (mm)
Graph 41
Minor Axis:
Machin
Major Axis:
Time
Edit
New
Results
Time (Seconds)

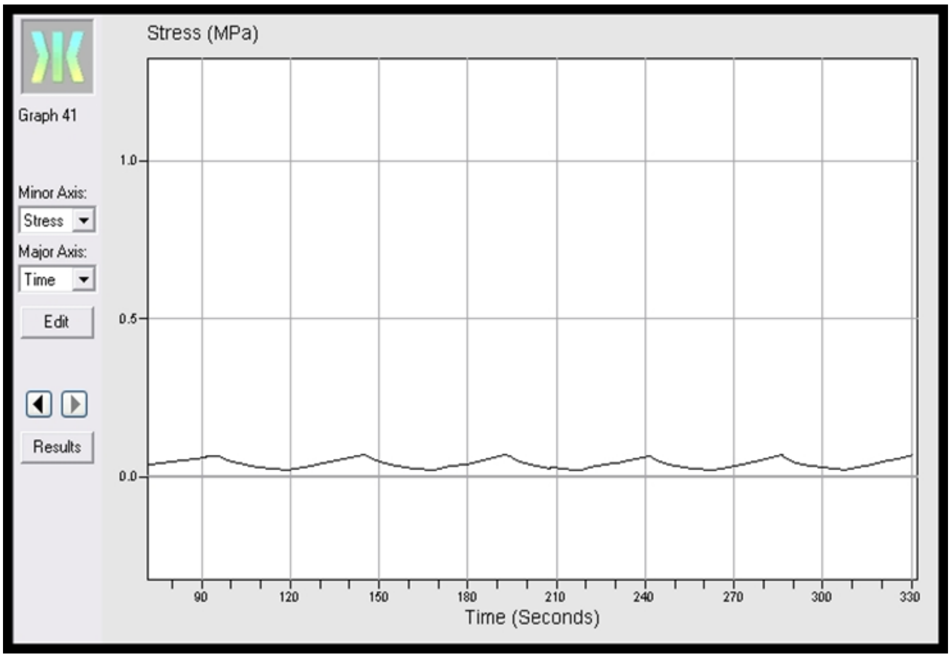
b)


Graph 41
Minor Axis:
Extensi
Major Axis:
Time
Edit
New
Results
Extension from Preload (mm)
13.0
12.0
11.0
10.0
9.0
8.0
7.0
90
120
150
180
210
240
270
300
330
Time (Seconds)

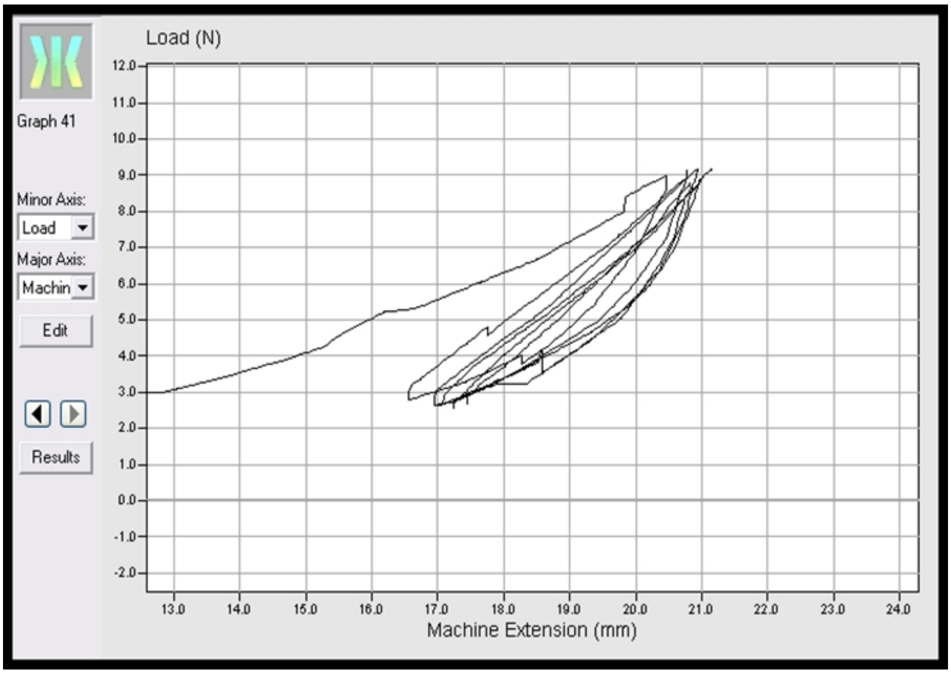
c)


Graph 41
Minor Axis:
Percen
Major Axis:
Time
Edit
New
Results
Percentage Strain
24.0
23.0
22.0
21.0
90
120
150
180
210
240
270
300
330
Time (Seconds)

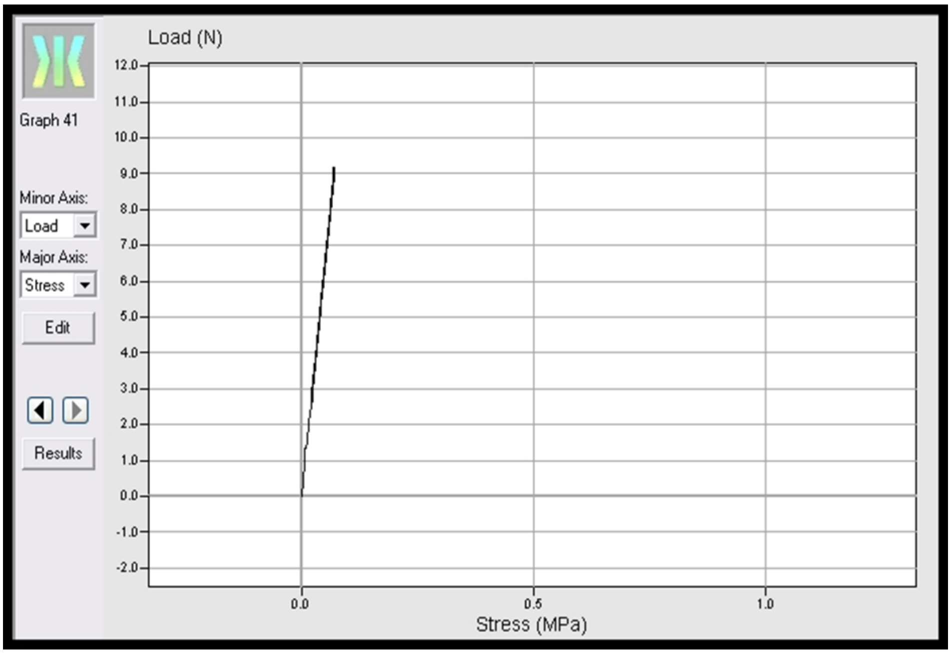
d)


Stress (MPa)
Graph 41
Minor Axis:
Stress
Major Axis:
Time
Edit
Results
1.0
0.5
0.0
90
120
150
180
210
240
270
300
330
Time (Seconds)

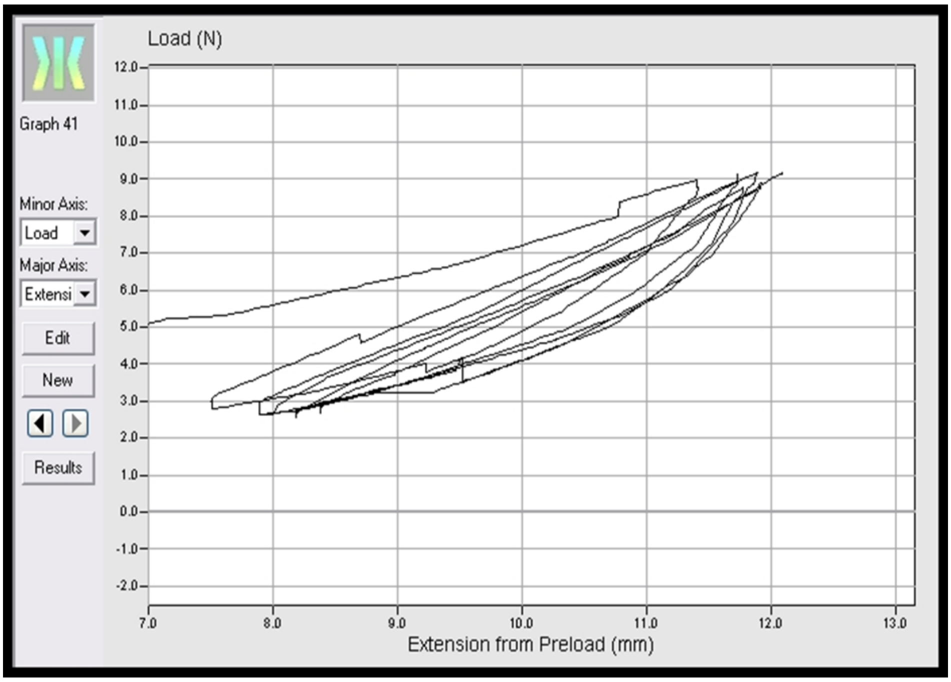
e)


Load (N)
Graph 41
Minor Axis:
Load
Major Axis:
Machin
Edit
Results
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
13.0
14.0
15.0
16.0
17.0
18.0
19.0
20.0
21.0
22.0
23.0
24.0
Machine Extension (mm)

f)


Load (N)
Graph 41
Minor Axis:
Load
Major Axis:
Stress
Edit
Results
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
0.0
0.5
1.0
Stress (MPa)

g)


Load (N)
Graph 41
Minor Axis:
Load
Major Axis:
Extensi
Edit
New
Results
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
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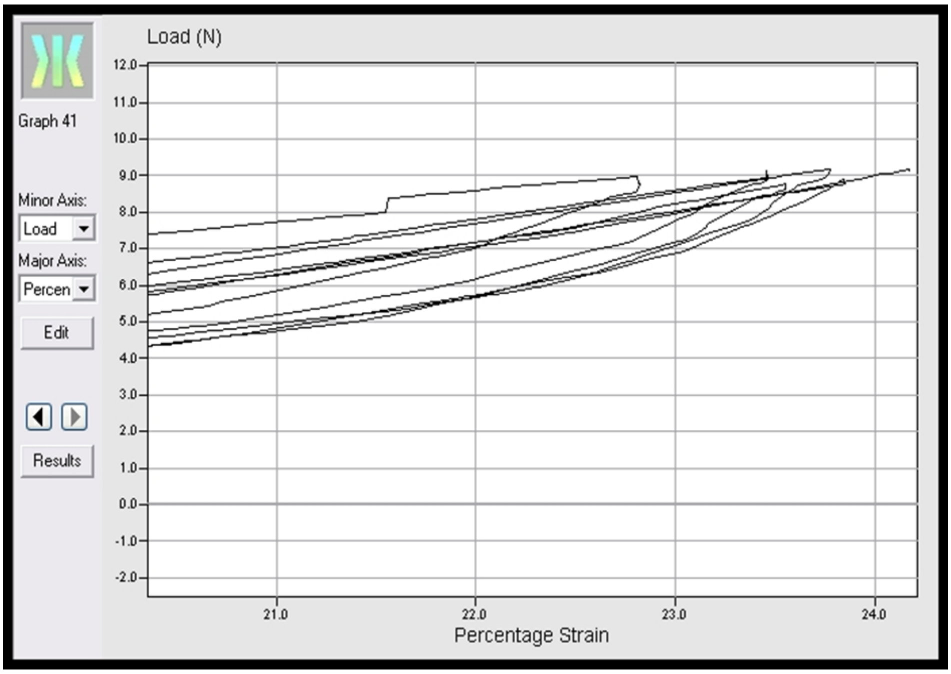
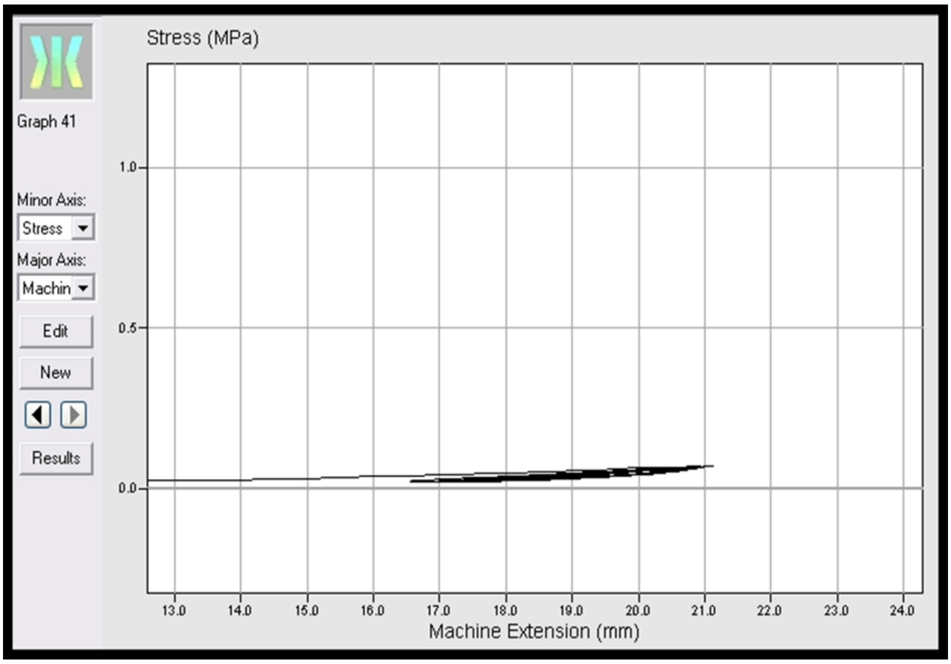
2.0
1.0
0.0
-1.0
-2.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
Extension from Preload (mm)

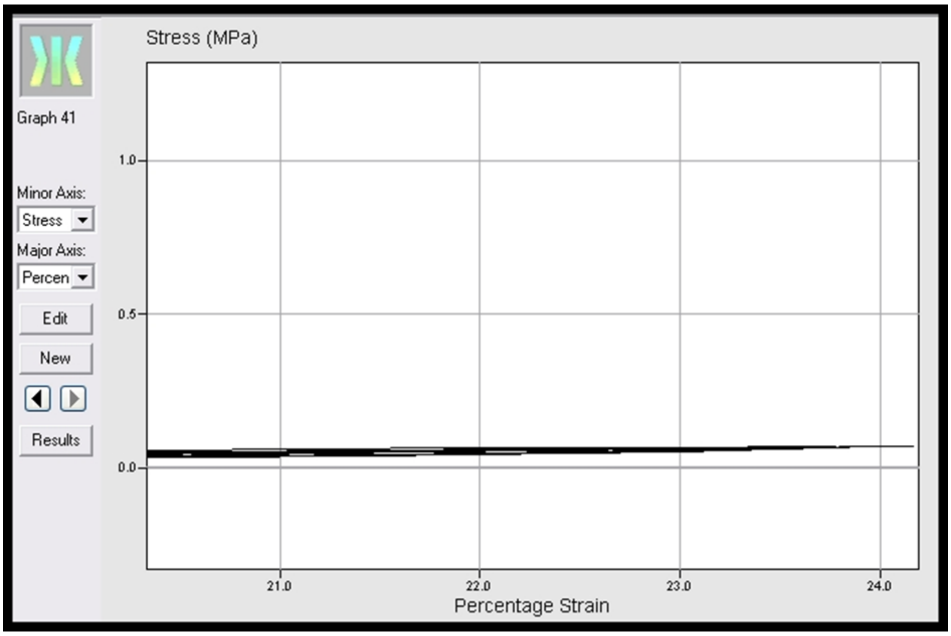
h)


Load (N)
Graph 41
Minor Axis:
Load
Major Axis:
Percen
Edit
Results
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
21.0
22.0
23.0
24.0
Percentage Strain

i)


Stress (MPa)
Graph 41
Minor Axis:
Stress
Major Axis:
Machin
Edit
New
Results
1.0
0.5
0.0
13.0
14.0
15.0
16.0
17.0
18.0
19.0
20.0
21.0
22.0
23.0
24.0
Machine Extension (mm)

j)



k)

Fig. 2 – Evolutions generated by the software.

4. Results and Discussion

At each test the data acquisitions were made in 16000 points and the values of the parameters were saved in "txt" format so that it is possible to export the data so that they can be processed in the MATLAB programming environment. For this purpose, a program has been designed that calculates the area of each hysteresis loop that appears on the force-stroke graphs of the machine (or force-stroke of the machine after the pretensioning phase), this parameter highlighting the amount of energy that is not returned by to the material (retained by the material) and which is an indication of its future behavior (elasticity, plasticity, wear over time). The program called "Arhist" is presented as follows:

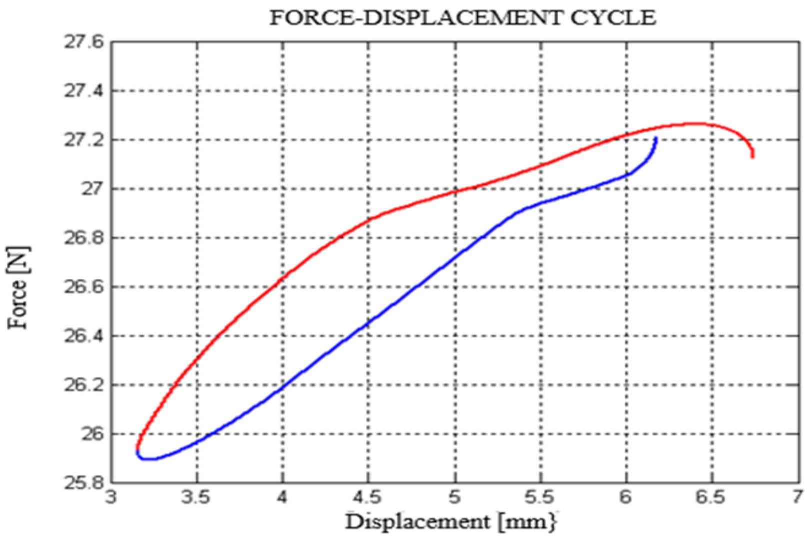
Program Arhist

```
close all;clear all;clc;tic
load data.txt;
x=data(:,1);y=data(:,2);z=data(:,3);w=data(:,4);
 p=500;
y=smooth(y,p);z=smooth(z,p);
%plot(y,z);
```

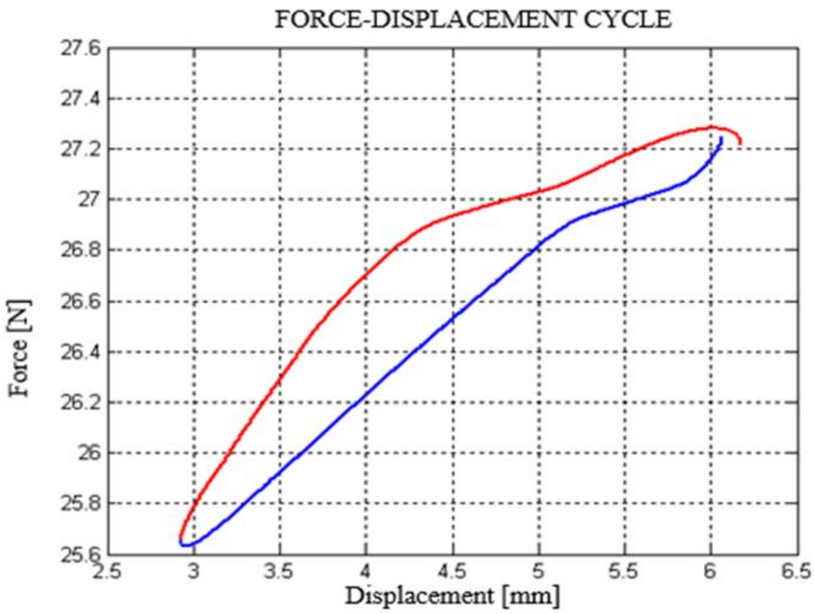
```
l=length(data);
k=1;
for i=7000:l-2;
   if y(i)<y(i+1);if y(i+1)>y(i+2);
   flag(k)=i+1;   k=k+1;
      else end
   else end
end
k=1;
 jap=1;% jap este numarul ciclului
for lip=jap:jap;
a=lip;b=a+1;
y1=y(flag(a):flag(b));z1=z(flag(a):flag(b));
l=length(y1);
y1(l+1)=y1(1);z1(l+1)=z1(1);
plot(y1,z1);
%l=l+1;
lpe2=l/2;
minim=1000;maxim=-1000;
for i=1:l
   if y1(i)<minim; minim=y1(i);k1=i;else end
   if y1(i)>maxim; maxim=y1(i);k2=i;else end
end
k1,k2
k2a=max(k1,k2);k1a=min(k1,k2);
if k1a>1;k2a=k1a;k1a=1;else end
arie1=0;
y2a=y1(k1a:k2a);y2b=y1(k2a:l);
z2a=z1(k1a:k2a);z2b=z1(k2a:l);
 plot(y2a,z2a,'r','LineWidth',1.5);hold on;plot(y2b,z2b,'b','LineWidth',1.5);
title('C I C L U  F O R T A - D E P L A S A R E');
xlabel('D e p l a s a r e [ m m ]');grid
ylabel('F o r t a  [ N ]')
%determinare locatie de intersectie
 comp=7.9076;%Valoare care se introduce manual pentru fiecare ciclu de
histerezis
 dif=1000;
for i=k1a:k2a
comp1=abs(y1(i)-comp);
if comp1<dif;dif=comp1;loc1=i;else end
end
dif=1000;
for i=k2a:l
```

```
comp1=abs(y1(i)-comp)
if comp1<dif;dif=comp1;loc2=i;else end
end
 %loc1=1;loc2=k2-1;
 arie1=0;
for i=loc1:k1-1;
    cotamedie=(z1(i+1)+z1(i))/2;
    arie=cotamedie*(y1(i+1)-y1(i));
    arie1=arie1+arie;
end
 arie2=0;
for i=k1:loc2-1;
    cotamedie=(z1(i+1)+z1(i))/2;
    arie=cotamedie*(y1(i+1)-y1(i));
    arie2=arie2+arie;
end
 arhis(k)=abs(abs(arie2)-abs(arie1))
%ARHIS ESTE ARIA CICLULUI D HISTEREZIS (LUCRUL MECANIC
NERECUPERAT DIN SISTEM
k=k+1;
end
%toc
```

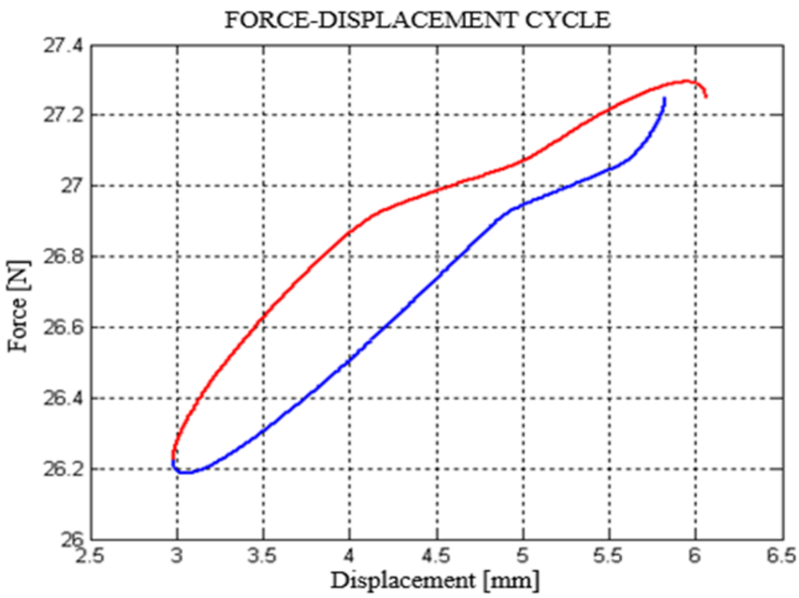
For each material the program generates the evolution of the force depending on the displacement for each stress cycle and calculates the area of the hysteresis cycle (an example is presented in Fig. 3).



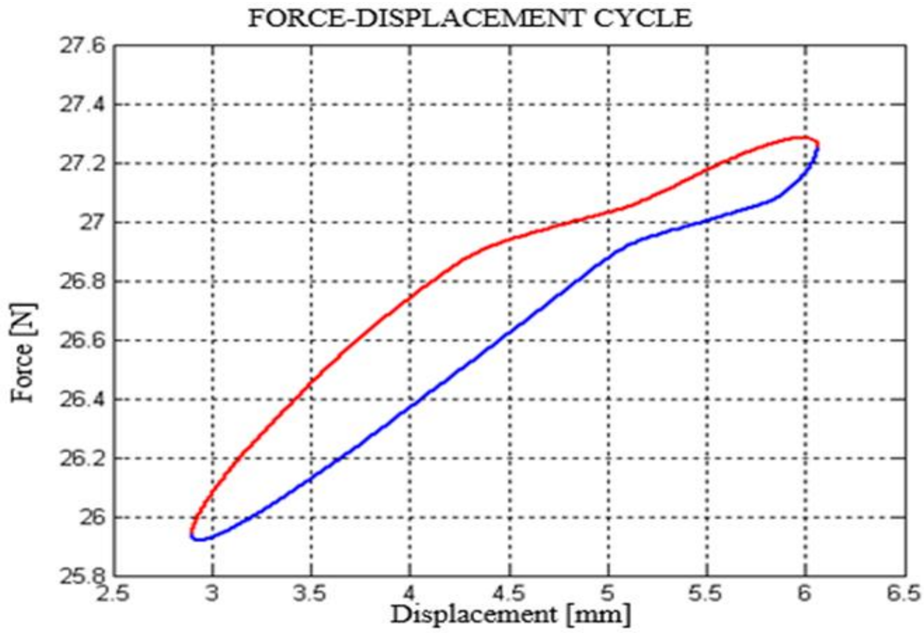
a) The first cycle



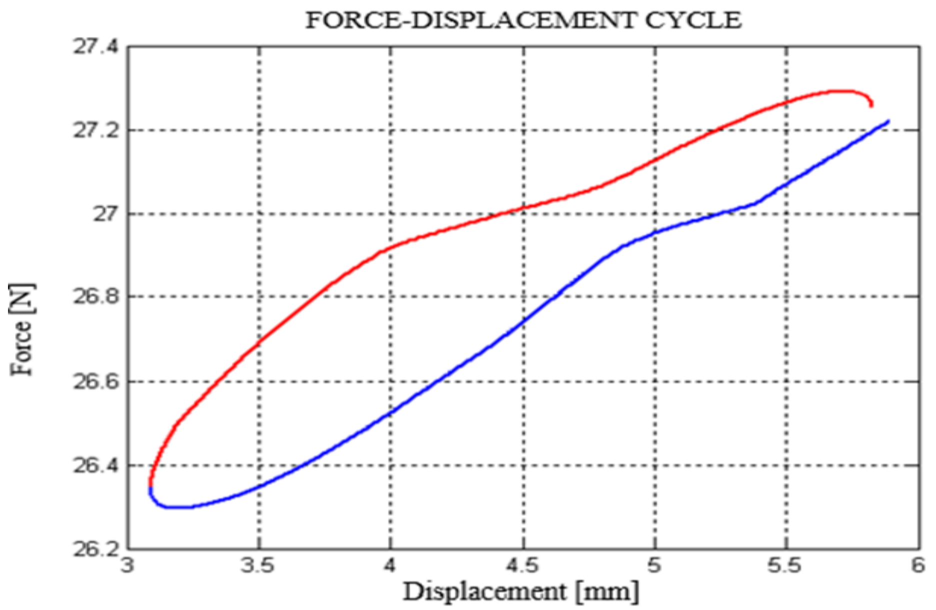
b) The second cycle



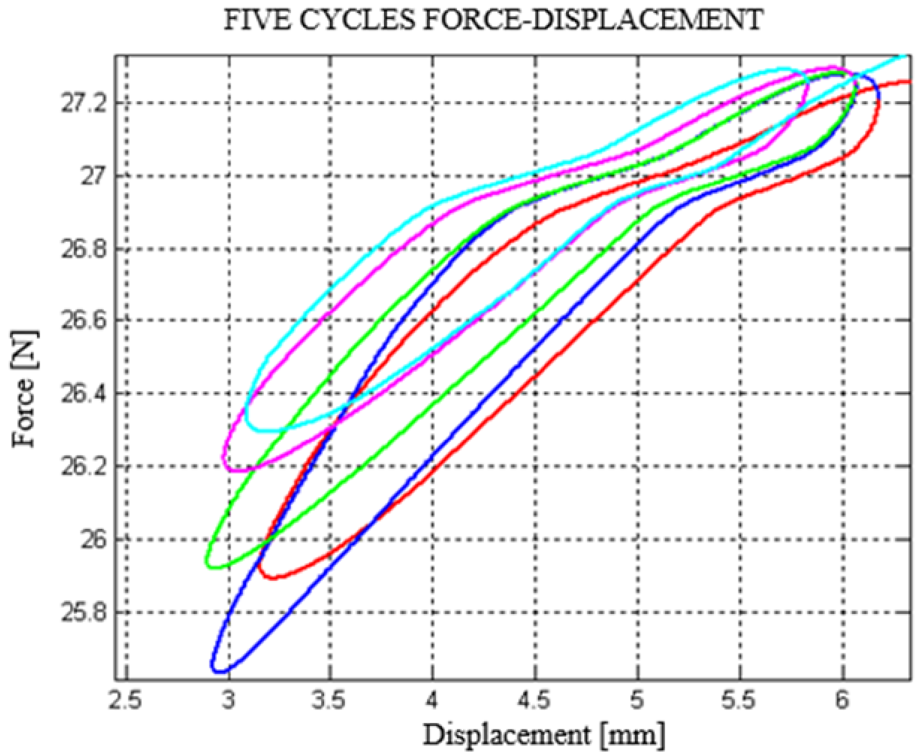
c) The third cycle



d) The fourth ccycle



e) The fifth cycle



f) All cycles

Fig. 3 – The evolution force-displacement for each stress cycle.

The areas calculated in this case are presented in Table 2

Table 2

The hysteresis cycle aria [N·mm]	Cycle 1
0.9366	Cycle 2
0.7861	Cycle 3
0.7061	Cycle4
0.7091	Cycle 5

For each material, the average value of the area of the hysteresis curves was calculated (results [N·mm] presented in Table 3 and Table 4).

Table 3

MUV1	MUV2	MUV3	MUV4	MUV5	MUV6	MUV7
1.1024	0.956	0.63056	1.23628	1.39684	1.06676	3.34686

Table 4

MBV1	MBV2	MBV3
0.6137	0.8032	0.76702

Analyzing these values we can say that the lowest average was obtained for MBV1 (but very close is also MUV3), while the highest average was obtained for MUV7. Considering that the areas of the hysteresis curves are proportional to the energy retained by the material, it follows that in an increasing order of the retained energy the materials could be ordered as follows:

1. **MBV1;**
2. **MUV3;**
3. **MBV3;**
4. **MBV2;**
5. **MUV2;**
6. **MUV6;**
7. **MUV!;**
8. **MUV4;**
9. **MUV5;**
10. **MUV7.**

5. Conclusions

The analysis of the values of the aerage area of the hysteretic curves leads to a hierarchy of materials.

These results can be interpreted as a capacity of the material structure to retain energy. This can be interpreted as a characteristic of the mechanical behavior of the material in case of heavy loads and therefore can give clues about the usefulness of future protective equipment.

REFERENCES

Hasçelik B., Eren R., *Development of a Test Device for Measuring Tensile Properties of Fabrics*, Tekstil ve Konfeksiyon, **26**, *1*, 12-21 (2016).

Roshan P., *High Performance Technical Textiles*, John Wiley & Sons Ltd. (2019).

Shishoo R.L., *Importance of Mechanical and Physical Properties of Fabrics in the Clothing Manufacturing Process*, International Journal of Clothing Science and Technology, **7**, *2/3*, 35-42 (1995).

Scott R.A., *Textiles for Protection*, 1st Edition, Woodhead Publishing (2005).

Ziegenfuß B., Klein N., *Management of Safety and Health Protection on Building Sites – Under Special Consideration of Use of Personal Protective Equipment*, Proceedings of NOKOBETEF 6 and 1st European Conference on Protective Clothing Stockholm, Sweden, May 7–10, 41-48 (2000).
Wang X., Liu X., Hurren C., *Physical and Mechanical Testing of Textiles. Fabric Testing*, Ed. H. Jinlian, England: Woodhead Publishing Limited and CRC Press LLC (2008).
https://www.jlwinstruments.com/products/products-library/lrx-series-materials-testing-machine/

METODA DE EVALUARE A PROPRIETĂȚILOR MECANICE ALE UNOR MATERIALE PE BAZA UNOR CURBE DE HISTEREZIS

(Rezumat)

Producția de echipamente de protecție noi, cu proprietăți superioare celor existente pe piață în acest moment, se poate face prin utilizarea de materiale noi, cu caracteristici mecanice superioare (Shishoo, 1995). Pentru a evalua aceste caracteristici, este necesar să se dezvolte o metodologie și să se utilizeze instalații experimentale adecvate, care să permită obținerea de rezultate concludente, pe baza cărora se pot trage o serie de concluzii cu privire la posibilitățile de utilizare a acestor materiale.

Această lucrare prezintă o instalație și o metodă de testare pentru evaluarea proprietăților mecanice ale unor materiale.