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EXPERIMENTAL RESEARCH ON THE CHOICE OF COMPOSITE MATERIALS REQUIRED FOR THE CONSTRUCTION OF THE PERISCOPE MOUNT ATTACHED TO ARTILLERY EQUIPMENT

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Abstract: *The authors of this scientific paper want to highlight, experimentally and analytically, the study of mechanical stresses performed on current materials that can be used in the construction of military artillery equipment, in the present case, the periscope mount. The scientific demarche goes through the following stages: experimental determination of mechanical characteristics corresponding to the studied materials (ertalon 4.6 and nanocellulose), using both the universal the Quasar 25 kN column testing machine for tensile stress and the Charpy pendulum for the breaking stress by performing an impact test; obtaining and interpreting the results supported by a mathematical modeling of the tensile strengths of the studied materials, analysis performed according to the linear elongation of deformation.*
Key words: *experiment, stretching, breaking, sample, nanocellulose, ertalon 4.6, mathematical modeling*

1. INTRODUCTION

The strength of materials is a technical discipline that studies the behavior of materials subjected to various stresses [Bej 05], [Dud 13]. Research in this field is mainly focused on industrial applications, such as new uses of metallic, plastic, ceramic materials, and of other non-metallic products in the construction of reliable parts that can be successfully assembled on the mechanical structure of civilian or military equipment.

The knowledge of the optical, electrical, chemical and mechanical properties of different materials enables researchers to choose the best material for a precise use and in accordance with the destination imposed by the beneficiary. Thus, it is necessary to know the mechanical behavior of materials (samples of ertalon and nanocellulose were selected for the present scientific research [Che 11], [Vol 17]) by determining the mechanical characteristics, and by obtaining their characteristic curve using as experimental methods — the tensile and rupture test [Aga & Pet 22].

Of all the mechanical tests, the tensile test is certainly a fundamental requirement, which is used to determine the main mechanical properties of materials, such as: the fundamental modulus of elasticity, the tensile strength/limit, the flow resistance, the breaking elongation and the elongation coefficient. Based on these experimental data, the corresponding characteristic curve can be obtained, which allows for the identification of the elastic and plastic area, the throttling area and the rupture of the materials/samples taken for the experimental study, respectively. [Car 08], [Nis 17].

2. EXPERIMENTAL STUDY

2.1 Tensile experimental analysis

In order to perform the experiment in the case of stretching stress for the two materials under study, a method of analysis on the universal testing machine, called the *Plastic Method,* was achieved. [Sta 14]. Determining the strength and plasticity characteristics of the materials at the stress presented above was done according to SR EN 10002/1-1997, applying to the specimens under study an axial increasing force (of max. 23 kN), usually until

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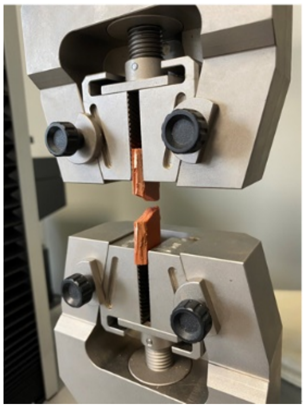
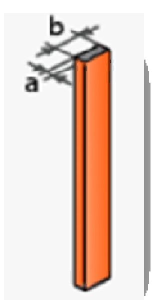
breaking, recording in this way the corresponding variations for its length (ertalon 4.6 and nanocellulose) (Fig. 1 a), b) and c)) [Sta 97].



a)

b)



c)

Fig. 1. Fragile ruptures: a) ertalon 4.6, b) nanocellulose, c) dimensions of the sample

Following the rupture of the two samples subjected to traction, a normal separation section occurred on the axis, obtaining thus their cross section. It is also mentioned that this type of rupture appears suddenly, without any previous manifestation, the two rupture sections presenting a grainy structure, visible under the microscope.

The scientific demarche was outlined in accurately establishing and highlighting the following strength parameters [Aga & Pet 22]:

a) determination of the breaking strength of the tested material, taking into consideration the value of the maximum force that appeared during the testing of the F_{max} samples divided by the initial section of the S_0 sample;

b) the determination of the relative elongation at rupture was made by breaking in the middle third of the length between the extreme parts of those two samples and the determination by direct measurement. The relative elongation at rupture, determined experimentally, is valid regardless of the position of the throttling, the value obtained by the machine falling within the prescribed limits for each of the tested materials.

Following the experimental measurements on the two studied materials, we obtained the graphs of the curves corresponding to the materials and the results for: a/L [mm], b/l [mm], σ_y [N/mm^2] (stress according to ISO 527-1), ε_y % (specific deformation), σ_m [N/mm^2] (maximum stress), σ_b [N/mm^2], F_t[N] (breaking load), E_t [N/mm^2] (modulus of elasticity) (Table 1, Figure 2).

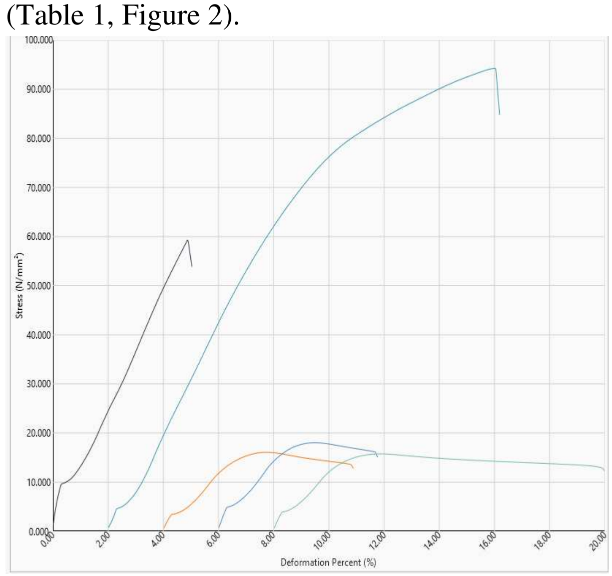


Fig. 2. Graphic results obtained from the experiment

Tab. 1. Values from experiments

No. sample	Type of material	a/L mm	b/l mm	v mm/min	σ_r N/mm^2	ε_y %	ε_m %	F_t N	E_t N/mm²
1	ertalon 4.6/sample 1	10.00	6.00	230	527.5	9.4	9.4	5655.8	1749.9
2	ertalon 4.6/ sample 2	10.00	6.00	190	518.5	4.9	4.9	3562.7	2817.3
3	ertalon 4.6/ sample 3	10.00	6.00	250	522	14.0	14.0	5652.8	1294.5
4	nanocellulose/ sample 1	10.00	4.00	250	421.5	3.7	3.7	565.1	1000.3
5	nanocellulose / sample 2	10.00	4.00	190	419	3.5	3.5	670.3	1468.4
6	nanocellulose / sample 3	10.00	4.00	230	418	3.9	3.9	536.4	1167.1

From the graphs presented above we could highlight, based on the drawing of the characteristic curve of the materials in coordinates representing the stress and deformation, the relevant conclusions for choosing the optimal material for the construction of the periscope mount for artillery equipment, namely: ertalon 4.6/sample 2, presents all the optimal conditions for the use of the material at a higher level of exploitation of the breaking strength. On the other hand, in nanocellulose, the breaking stresses are much lower (up to 670.3 N), but in sample 3 the deformation increases up to about 3.9 %, which ensures an optimal elasticity of the material. The ertalon 4.6 material has better mechanical properties compared to nanocellulose.

2.2 Experimental analysis at rupture

As previously presented, the sample that obtained the experimental "*vote of confidence*" was subjected to a practical rupture test, an experiment carried out by using the Charpy Pendulum- type of device (hammer) (Fig. 3).

The final results obtained according to the characteristics and dimensions of the material for ertalon 4.6 are highlighted on the receipt issued by the apparatus, after performing the breaking impact:

- ➢ breaking power (Ak = 54.99 kJ/m^2);
- ➢ the kinetic energy of the breaking impact W = 21.940 J).

2.3 Preliminary conclusions

The comparative analysis and the possibilities of implementation are presented based on the data provided in the present study, the main advantages and disadvantages associated with the materials proposed for the experimental study being highlighted below:

Advantages:

a. ertalon 4.6/sample 3 can withstand loads of up to about 5652.5 N with a deformation of about 14%;

b. nanocellulose/sample 3 can withstand a much lower load, but the deformation can reach 3.9%;

c. ertalon 4.6/sample 3 is used for high loads;

d. for large deformations nanocellulose/sample 3 is used. Nanocellulose/sample 1 and nanocellulose/sample 2 are not recommended for use at high stresses or large deformations.

Disadvantages:

a. the other materials of the analyzed samples, ertalon 4.6/sample 1 and ertalon 4.6/sample 2, respectively, are not indicated for use in terms of the strength of the material.

Fig. 3. Testing of ertalon 4.6 material at breaking

3. MATHEMATICAL MODELING OF TENSILE STRENGTHS ACCORDING TO LINEAR ELONGATION AT DEFORMATION

Taking into consideration the experimental results obtained and centralized in table 2 and 3 respectively, and taking into account the deformation suffered by the sample subjected to the tensile test (Fig. 4), a mathematical model can be established to highlight the breaking strengths according to the linear elongation at deformation.

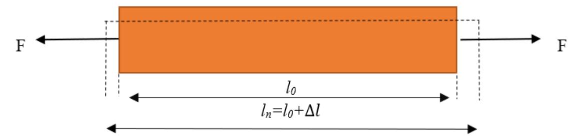


Fig. 4. Test piece subjected to tensile test: l_0 length sample, tensile stress with axial forces F, the sample elongates at l_n

We noted with: σ_{rSTASe}, σ_{rSTASn} – the tensile strength of the ertalon 4.6 based material and nanocellulose, respectively, and with σ_{r1}, σ_{r2}, σ_{r3}, σ_{r4}, σ_{r5}, σ_{r6} — the average tensile strengths of the specimens taken from the ertalon 4.6 and nanocellulose sample.

It is considered that the tensile strengths of the specimens taken from the samples under study vary with the linear deformation lengths according to the tensile strengths of the basic materials, according to the following relation:

$$\sigma_{rPS}(\Delta l) = \sigma_{MB} f(\Delta l), \quad (1)$$

Tab. 2. Values of the tensile strength parameters of the ertalon 4.6 material

No.	Basic material / sample	Linear elongation Δl at deformation (mm)		Tensile strength (N/mm^2)	
1.	Ertalon 4.6	Δl_{ie}	0	σ_{rSTASe}	527
2.	Ertalon 4.6 (sample 1)	Δl_{1e}	215	σ_{r1}	527.5
3.	Ertalon 4.6 (sample 2)	Δl_{2e}	234	σ_{r2}	518.5
4.	Ertalon 4.6 (sample 3)	Δl_{3e}	210	σ_{r3}	522

Tab. 3. Values of the tensile strength parameters of the nanocellulose material

No.	Basic material / sample	Δl linear elongation at deformation (mm)		Tensile strength (N/mm^2)	
1.	Nanocellulose	Δl_{in}	0	σ_{rSTASn}	424
2.	Nanocellulose (sample 4)	Δl_{4n}	210	σ_{r4}	421.5
3.	Nanocellulose (sample 5)	Δl_{5n}	234	σ_{r5}	419
4.	Nanocellulose (sample 6)	Δl_{6n}	215	σ_{r6}	418

which relation is adapted to the present research after an experimental tensile procedure of welded specimens and in which [Hâț 18]:
σ_{rPS} - represents the average tensile strength of the specimens from the ertalon 4.6 sample and nanocellulose, σ_{MB} - represents the tensile strength of the basic material, Δl - represents the linear elongation at deformation.
The aim was to determine the f (Δl) functions for the two basic materials (ertalon 4.6 and nanocellulose).

3.1 Mathematical modeling for the ertalon 4.6 sample

Applying the mathematical modeling, performed by means of the Matlab software, the following numerical data are obtained:
$f_0 = 1.0138304013830401383040138304013830 4$,
$f_1 = 1.1530437153043715304371530437153043 7$,
$f_2 = 1.0606770360584095547885370087796643 8$,
$\Delta l_{1e} = 215$, $\Delta l_{2e} = 234$, $\Delta l_{3e} = 210$.
After derivation and simplification, a system of three equations with three unknowns was obtained. To determine the three unknowns, Cramer's rule was used, and in Figure 5 the distribution of the tensile strengths for the ertalon 4.6 sample was represented graphically. Thus, the following numerical values were obtained:
- the determinant of
$$z = -2.6804390179769482E6,$$
- the determinant of
$$y = 2901584.031213972,$$
- the determinant of
$$x = -105178.26765496314,$$
- the determinant of the system
$$D = -2.5408290470172756E6,$$
and the following solutions of the system resulted:
$$z = 1.0437746,$$
$$y = -0.012244735,$$
$$x = 2.2058086E- 2.$$
In other words, the average tensile strength of the basic material according to the linear elongation varies according to the relationship:
$$\sigma_{rPS}(\Delta l) = \sigma_{rMB}(\Delta l)\ (2.2058086E - 2\Delta l^2 - 0.012244735\Delta l + 1.0437746). \quad (2)$$

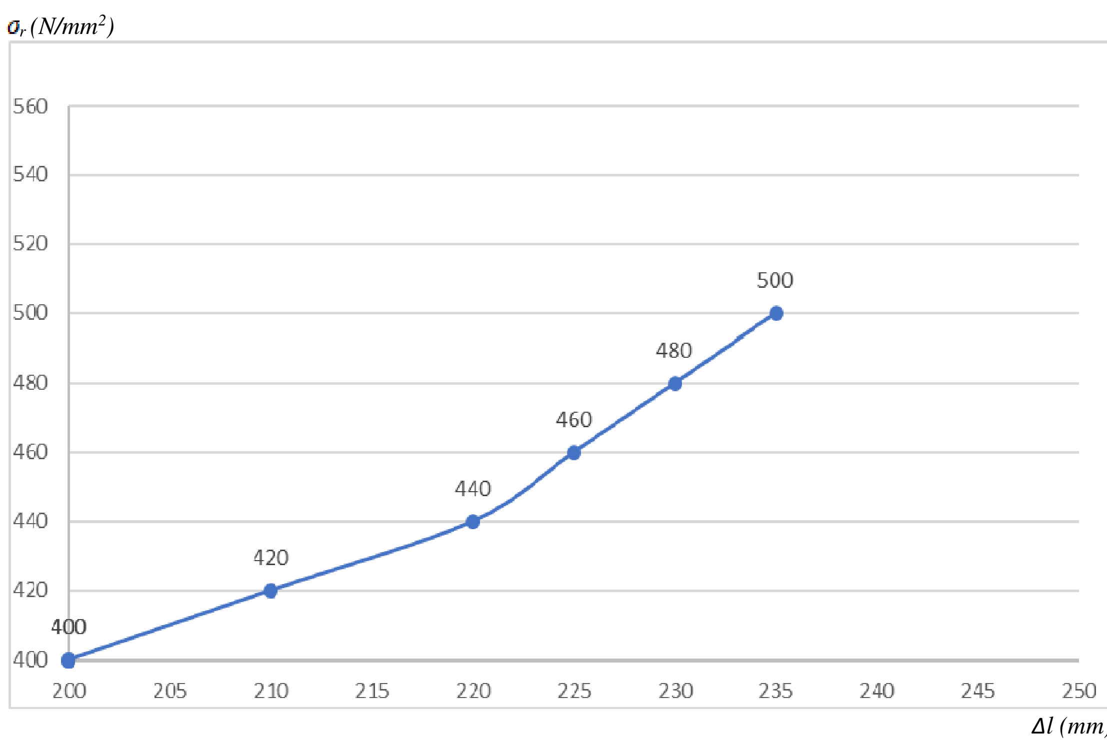


Fig. 5. Distribution of the tensile strengths of the ertalon 4.6 sample depending on the linear elongation at deformation

3.2 Mathematical modeling for the nanocellulose sample

Similar to the procedure presented above, the following numerical data were obtained according to the mathematical modeling performed in Matlab:

$f_0 = 0.833026781279422667103299687153 07$,
$f_1 = 0.865320984257711642542230164282 34$,
$f_2 = 0.917084442763454658866554728328 76$,

$\Delta l_{4n} = 210$, $\Delta l_{5n} = 234$, $\Delta l_{6n} = 215$.

Thus, a system of three equations with three unknowns was obtained. Cramer's rule was used again to determine the three unknowns.

Then, the following numerical values were obtained:

- the determinant of

$$z = -2.285570285538267E6,$$

- the determinant of

$$y = -476536.6398407243,$$

- the determinant of

$$x = 15502.638886661021,$$

- the determinant of the system

$$D = -15507.94888666E0131.$$

Thus, the following solutions of the system resulted:

$$z = 0.8115364,$$
$$y = 0.1125748837,$$
$$x = -3.2678876E3.$$

In other words, the average tensile strength of the nanocellulose basic material according to the linear elongation has the expression:

$$\sigma_{rPS}(\Delta l) = \sigma_{rMB}(\Delta l)\ (-3.2678876E3\Delta l^2 - 0.1125748837\ \Delta l + 0.8115364). \quad (3)$$

Figure 6 shows the distribution of the tensile strengths of the nanocellulose material according to the linear elongation at deformation.

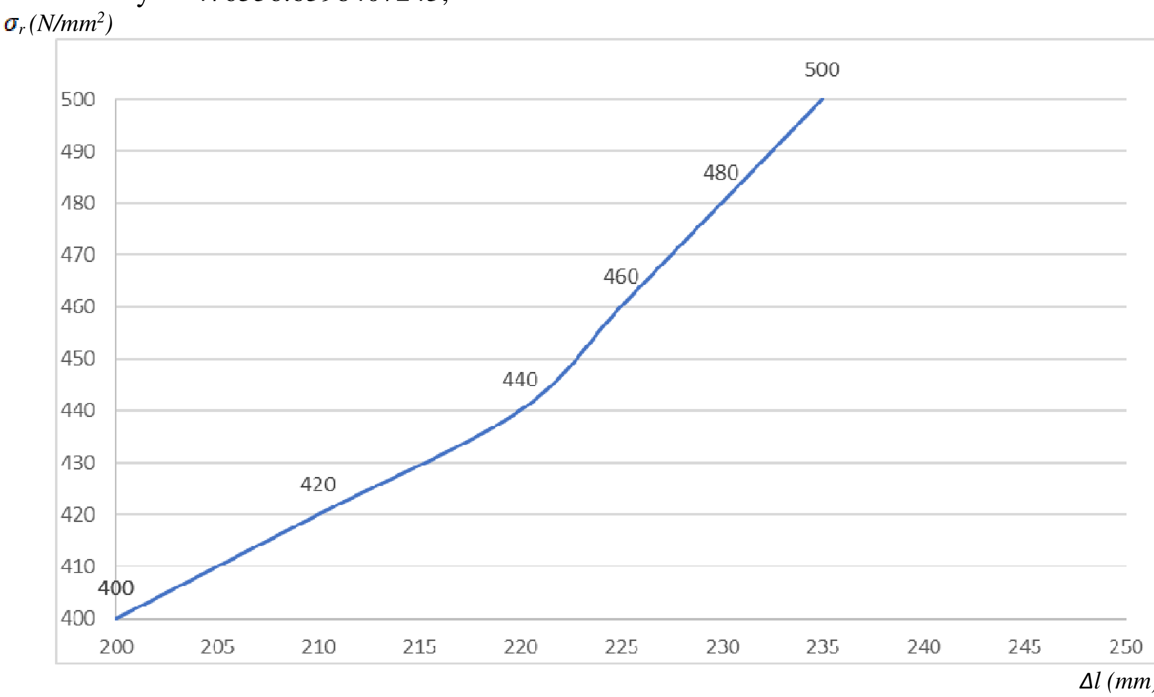


Fig. 6. Distribution of tensile strengths of the nanocellulose sample as a function of linear deformation elongation

The distribution graphs show that there is a functional dependence between the tensile strengths of the basic materials and the linear elongations at deformation, which is approximated by a function with a parabolic variation. The more accurate the experimental results, the more faithfully the mathematical model describes the studied process.

4. FINAL CONCLUSIONS

The scientific demarche materialized in:

a) the experimental determination of mechanical characteristics corresponding to the studied materials (ertalon 4.6 and nanocellulose), using the universal column testing machine for tensile/stretching stress.

In this case, the results obtained experimentally, showed that these mechanical strength characteristics may have different values, depending on the experimental conditions, on the dimensions of the samples, the strength speed, and the characteristics of the testing machine, respectively.

Moreover, the graphs presented in the paper show that sample 2 (ertalon 4.6) presents all the optimal conditions for the use of the material at the upper level of the exploitation of the breaking strength, being the material that can be used in the construction of the mount of the periscope attached to various military artillery equipment.

b) experimental achievement of some mechanical characteristics for the studied materials, with the help of the gravitational pendulum (in this case, the breaking test), at the Charpy test and at the Izod impact test, all these corroborated with mechanical processing, according to ISO standards, of some tested nylon samples with the help of the broaching machine.

In this case, the processing was performed on the optimal material, highlighted at point a), the data being recorded on the receipt issued by the device. In this case, too, the advantages and disadvantages of the studied samples were highlighted.

c) obtaining and interpreting the results were also supported by a mathematical modeling of the tensile strengths of the materials under study, analysis performed according to the linear elongation at deformation.

In this case, the validated scientific hypothesis demonstrated that the tensile strengths of the specimens taken from the studied samples vary depending on the linear elongations at deformation depending on the tensile strengths of the basic materials, after an innovative calculation relation and adapted to the current experimental requirements.

The mathematical modeling validated the results that were obtained, and the calculation demarche was performed by means of specific software.

The conclusion highlighted that the more accurate the experimental results, the more accurately the mathematical model describes the studied process, obtaining a functional dependence approximated by a function with the parabolic variation between the tensile strengths of the basic materials and the linear elongations at deformation.

While sample 3 (ertalon 4.6) shows optimal conditions for the use of the material at a higher level of exploitation of the breaking strength, nanocellulose (sample 3) ensures the optimal elasticity of the material. Hence, the fact that the ertalon 4.6 material has the optimal characteristics to be used in the construction of the periscope mount that can be fixed on various pieces of military artillery equipment, such as: the 120 mm caliber launcher, the M1955 152 mm caliber howitzer or the M1977 100 mm caliber anti-tank cannon.

5. ACKNOWLEDGEMENT

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CERCETARE EXPERIMENTALĂ PRIVIND ALEGEREA UNOR MATERIALE COMPOZITE NECESARE CONSTRUCȚIEI SUPORTULUI DE LUNETĂ ATAȘAT PE ECHIPAMENTE DE ARTILERIE

Rezumat:*Autorii prezentei lucrări științifice doresc să evidențieze, experimental și analitic, studiul unor solicitări mecanice efectuate pe materiale de actualitate ce pot fi folosite în construcția unor echipamente militare de artilerie, în speță, suportul lunetei. Demersul științific parcurge următoarele etape: determinarea experimentală a unor caracteristici mecanice corespunzătoare materialelor luate în studiu (ertalon 4.6 și nanoceluloză), utilizând atât mașina universală de testat pe coloane Quasar 25 kN pentru solicitarea la tracțiune cât și pendulul Charpy pentru solicitarea la rupere prin efectuarea unei testări de impact; obținerea și interpretarea rezultatelor susținută de o modelare matematică a rezistențelor de rupere la tracțiune a materialelor luate în studiu, analiză efectuată în funcție de lungirea lineară de deformare*

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