Comparative Analysis of the Mechanical Behaviour of Optical Sighting Devices Made of Plastic or Metallic Materials

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In order to design/redesign an optical sighting device used on an automatic weapon, several issues related to the behaviour under loads that appear during shooting should be taken into account .Also, in order not to influence the effectiveness of the weapon, the mass and the volume of the device must be as small as possible. In this paper, a comparative analysis of the behavior of the the ensemble sighting device - clamping system, subject to inertia forces is undertaken in the following two cases: the ensemble parts are made of duralumin and, in the second case, of polyester resin. The study is performed by means of numerical calculus, on the model being applied an acceleration in steady state mode.

Keywords: sighting, optical, finite element, plastic material

During the recoil, the weapon movement occurs with very large accelerations in opposite direction towards the one the bullet moves [2]. This makes the structure of the sighting device attached to the weapon, to be loaded with inertia forces. The loads, which are occurring in the clamping components of the sighting device, decrease with its weight. This explains the need to use certain materials with low density to manufacture optical sighting devices.

In this paper, it is studied the particular case of an open reflex finder mounted by means of a Picatinny rail and an adjustment piece on a weapon of assault. Two numerical calculations are carried out in order to review the possibility of using a plastic material instead of a metallic one (duralumin is commonly used nowadays) for producing the mechanical structure of the ensemble sighting device - clamping system.

Aiming at modeling the structure of the ensemble, in a first stage of finite element numerical calculus one can take into account the contact between the mechanical components of the assembly formed by the device with its clamping system on the weapon.

On the developed model, an acceleration in steady state mode was applied, the loading with inertia force was simulated and the distribution of stresses and strains was obtained in the two cases.

On the models of structures, the effect of the mass can be neglected, in a static analysis performed to obtain stresses, strains or displacements. Loads may be forces, pressures, inertia forces in steady state, imposed displacements, deformations caused by known thermal loads.

Static analysis can be linear or nonlinear. In a linear analysis, the simplest one, a linear system of algebraic equations is solved. Nonlinear analysis is solved by incremental and iterative methods (Newton - Raphson) [1, 3].

The analyzed structure

The optical device studied in this paper (fig. 1.a) is composed of:

- Picatinny rail (fig. 1.b);
- The adaptation part and the body of the sighting device (fig. 1.c).

The calculus model

The geometry of the analyzed structure is shown in figure 2. The model contains the mechanical parts of the whole ensemble composed of sighting device with its clamping system on the weapon and the main electronic components that are part of optical sighting device.

In figure 3, the geometry of the modeled mechanical parts and the electronic components are shown. Legend of this figure presents the materials defined in the finite element analysis for the first case study (ensemble made

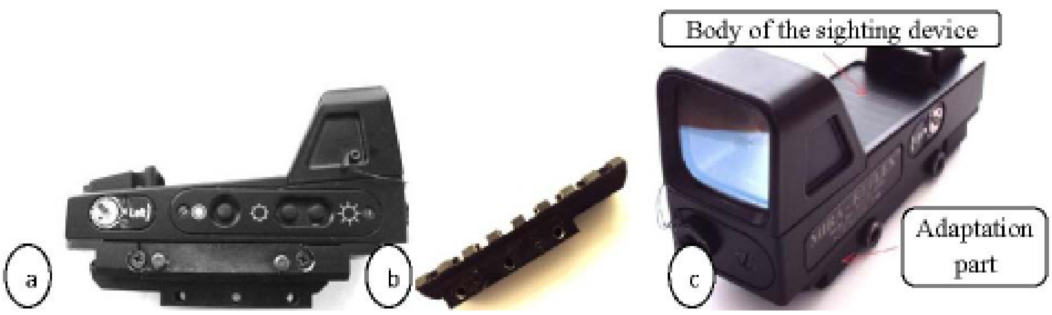

Fig. 1. Sighting device components

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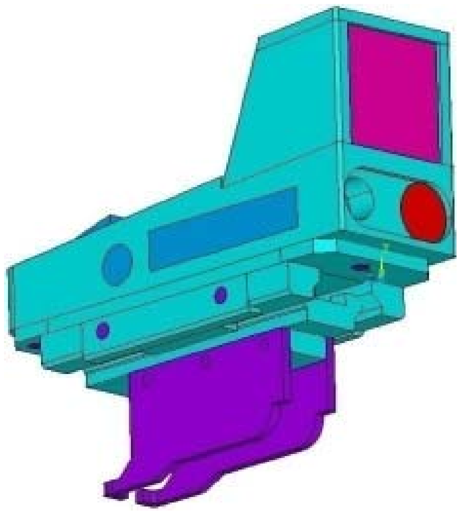

Fig. 2. Geometry of the analyzed structure

of duralumin).

The constitutive elements are:

- the body of the device (1){A};
- the adjusting body for Picatinny rail (2) {A};
- Picatinny rail (3) {A};
- object glass (4) {A};
- the ensemble for the transmission of the light beam (5) {D};
- the system on/off and brightness adjustment system for the graticule (6) {D};
- the control system of the graticule in the horizontal plane (7) {D};
- pieces for attaching on the rail (8) {A};
- battery (9) {E};
- pieces for the grip on the weapon (10) {B};
- screws (11) {B}.

The characteristics of materials are shown in table 1.

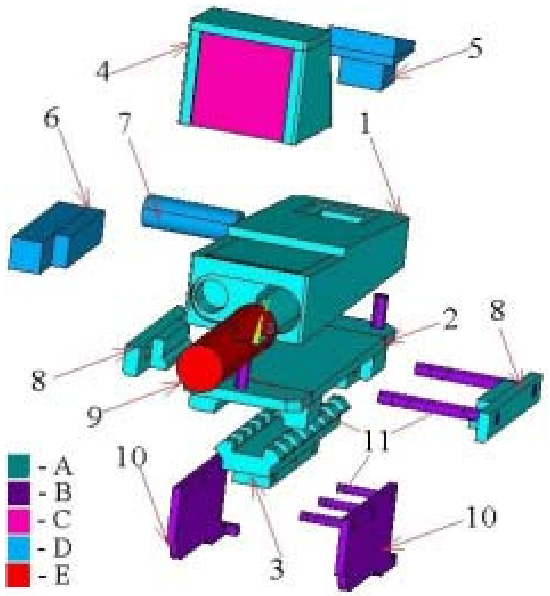

Fig. 3. Geometry of the mechanical parts and optical components

For the second numerical calculation, duralumin was replaced with polyester resin [4,5] having the following characteristics: E = 3480 MPa; ν = 0.28 and ρ = 1195 kg / m^3. Except for this change, the model was the identical in both calculations.

For the mesh of the structure hexahedral finite elements were used [6].

Constrained were applied on areas on the clamping parts of the weapon in contact with the uplifting block, the

Table 1
MATERIAL CHARACTERISTICS DEFINED

Material	Name	Young's modulus [MPa]	Poisson's ratio[-]	Density [Kg/m3]
A	Duralumin	70000	0.33	2700
B	Steel	210000	0.3	7850
C	Glass	70000	0.22	2500
D	*	210000	0.3	1500
E	**	70000	0.34	2950

part of the weapon that secures the device.

In figure 4, the mesh of structure and boundary conditions imposed on the structure are shown.

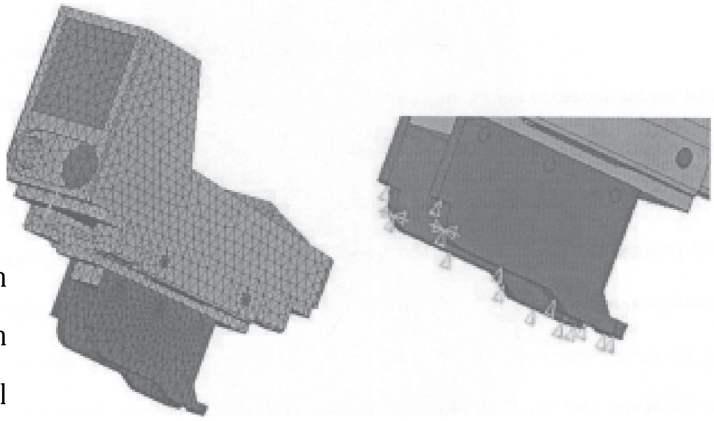

Fig. 4. Mesh structure and constraints

A total number of 23 pairs of contact elements were introduced between the bodies in contact of the model (fig. 5.a). In figure 5.b are illustrated in detail the elements added for the contact between the Picatinny rail and the adaptation part, grouped into six pairs.

Sighting devices and monoculars along with their clamping parts on the weapons, were tested at different accelerations depending on the weapon or the class of weapons to which they are attached to. On the websites of the manufacturers are listed acceleration values in the technical characteristics of sighting devices, to which these devices are guaranteed. Accelerations may range from values of tens of *g* (the gravitational acceleration) for apparatus intended for weapons with modest recoil energies and speeds up to values of 5000 *g* [7-8].

The optical device analyzed in this paper is intended for AKM assault weapons. Given the modest recoil of this weapon and the acceleration values to which such sighting devices are subject to, an acceleration value of 50 *g* was chosen in this analysis. Thus, the load consists of a global

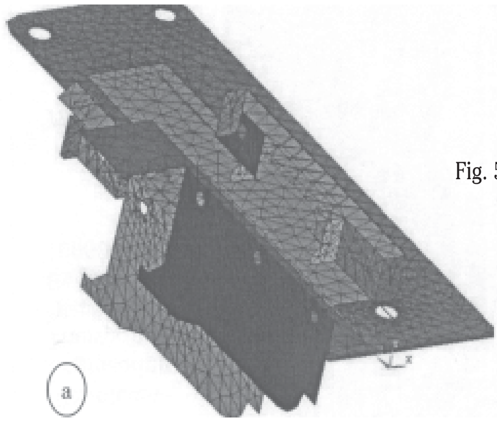

Fig. 5a

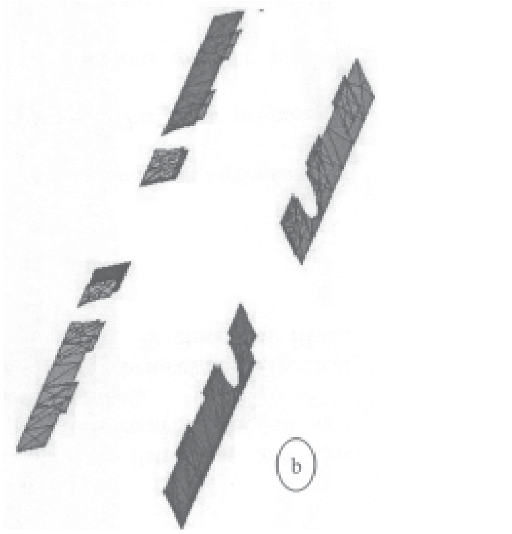

Fig. 5. The defined contact elements (a)
and detail of the elements defined between the Picatinny rail and the adaptation part (b)

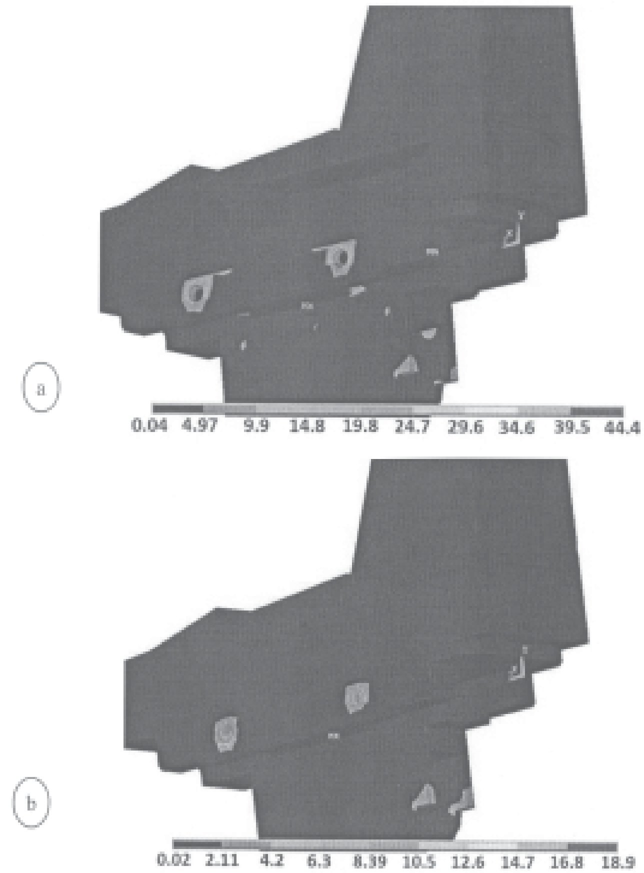

Fig. 6. Equivalent von Mises stress [MPa], for the structure made of duralumin (a) and the structure made of plastic material (b)

inertia force given by an acceleration of 500 m / s^2.

Results and discussions

From the large volume of results obtained in these analyzes just a few data about stress and displacements were selected and processed. In figure 6, the von Mises equivalent stress fields, obtained in the two analyzed cases were obtained. One can notice that the highest values of the stress are in the zone of the screw holes. For a better visualization of the results, in figure 7 are shown separately the maps of the equivalent stress for the clamping pieces on the rail, which are elements of duralumin or polyester

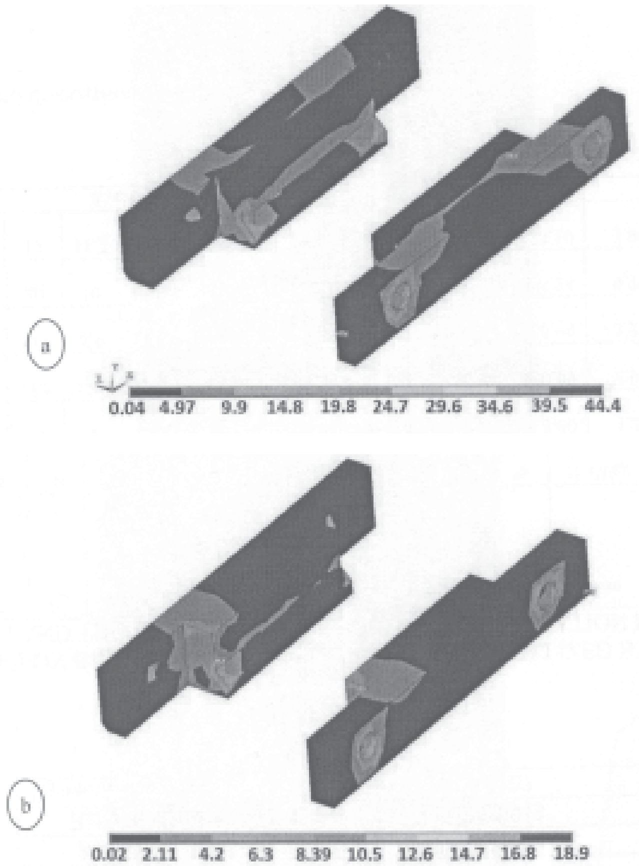

Fig. 7. Equivalent von Mises stress [MPa] for the most loaded components made of duralumin (a) and polyester resin (b)

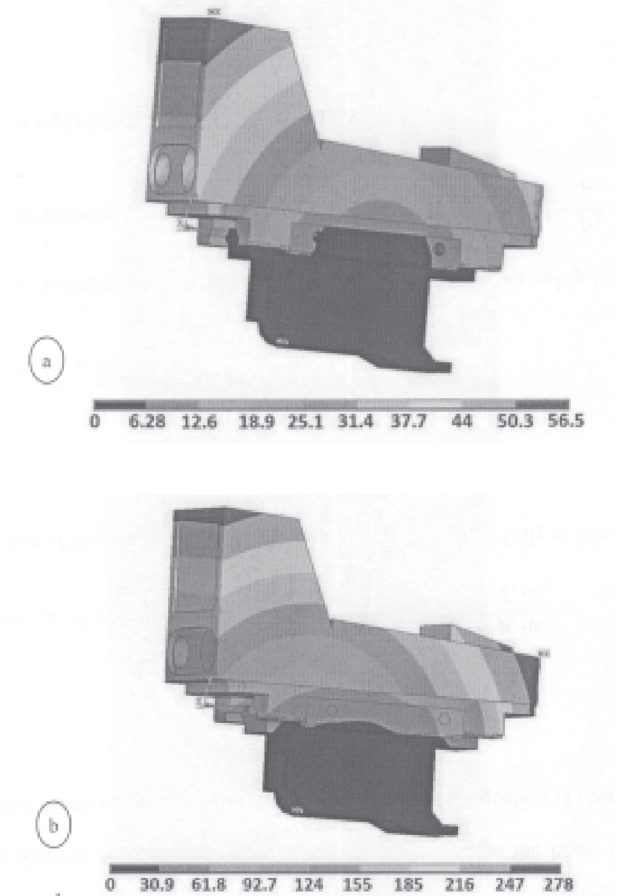

Fig. 8.The field of the total displacements [m] for structure made of duralumin (a) and structure made of plastic material (b)

resin, for which the stress reaches the highest values. For the other components of the ensemble, loadings are small or insignificant and the results are not relevant.

The value of the equivalent stress in the first case is 44.4 MPa in one of the pieces of duralumin. In the second case, the maximum value of the von Mises equivalent stress is 18.9MPa. In both cases, stress does not exceed the ultimate tensile strength for the two materials (≈100 MPa – duralumin and ≈ 30MPa – polyester resin) [9].

The displacements fields are consistent with the expected distribution. In view of the boundary conditions and the imposed loads, the structure tends to rotate about its centroid, as it is shown in the maps in figure 8. This can be considered as a normal behavior of the structure.

Conclusions

Given that the maximum stress of the most loaded pieces of the ensemble do not exceed the ultimate tensile strength of the materials in both studied cases, the polyester resin may be chosen for manufacturing the mechanical parts of such optical device;

The main advantages of using a plastic material in this area are:

- diminution of the mass of the device, of the inertia force acting on it, and also of the entire weapon on which it is mounted;

- since plastic materials are superior to metals from the point of view of casting processing, it is possible to change very easy the design of the component parts of the ensemble, and improved shapes and sizes can be obtained without significant costs.

In a detailed study, taking into account the exploitation conditions for a proper functioning of a weapon (strong shocks, high temperatures, assembly and disassembly repeatedly etc.), one can analyze the possibilities to use for manufacturing of such optical device a composite material with superior mechanical properties than polyester resin [10,11].

The study in this paper is motivated by the trend in the industry, to achieve optical sighting devices as small as possible, in order not to obstruct the shooter field of view, and from lightweight materials so that the weight of the weapon is not increased.

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Manuscript received: 8.10.2013