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STUDIES AND RESEARCHERS CONCERNING GRENADE LAUNCHER WITH HIGH-LOW PRESSURE CHAMBERS

In this paper are presented some aspects concerning grenade launcher with high-low pressure chambers. On the bases of mathematical model of firing phenomenon for this ballistic system was elaborated interior ballistics software. With the aid of this software were studied the variation of gases pressure and grenade velocity versus time and displacement, as well as the influence of different parameters on main ballistic magnitudes.

For an extant such ballistic system, the theoretical results obtained with the aid of interior ballistics software and experimental data are compared.

1. Introduction

The grenade launcher with high-low pressure chambers, named the grenade launcher with double chamber or gas dynamic grenade launcher, belongs of the class of weapons with gases flows. The gases resulted from burning of propellant (powder) in the high-pressure chamber (combustion chamber) flow though one or more nozzles (orifices) in the low-pressure chamber (weapon chamber), where act on the grenade and increase its velocity.

The general organization of a grenade launcher with double chambers is shown in Figure 1.

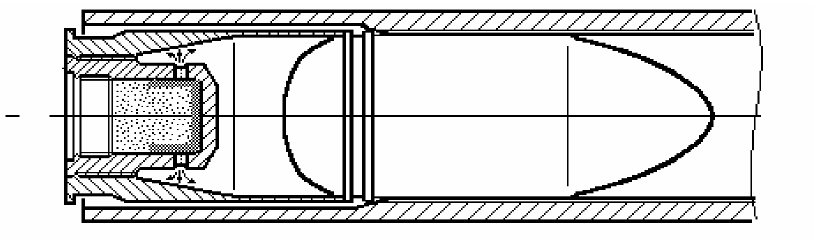

Figure 1. The scheme of the grenade launcher with double chamber

This weapons class achieves some advantages, thus: small thickness of barrel and grenade walls, which leads to the increasing of filling coefficient of grenade and to the decreasing of barrel mass; the replacement of steel with another materials for the manufacture of barrel and grenade.

The firing phenomenon with these weapons, for study, is divided in following periods: the preliminary period, between the inflaming of powder and the beginning of grenade motion; first (main) period, until the finishing of powder burning; second (adiabatic) period, between the finishing of powder burning and the leaving of barrel by grenade.

The significance of the used notations in this paper is that accepted in the speciality literature [1], [5], [7], [8].

2. Assumptions

The mathematical model, which describes the ballistic cycle in a grenade launcher with high-low pressure chambers, was elaborated accepting following simplified hypotheses [2], [5], [8], [9], [10], [11]:

a. The charge of propellant burns in accordance with geometrical law of powder (propellant) burning;

b. The mixture of gases and unburnt powder is homogeneous;

c. The high-low pressure chambers have the same cross section as the groove part of barrel;

d. The density of mixture is the same in all sections of the barrel;

e. The flow of mixture is considered as one-dimensional and steady state;

f. The velocity of unburned particles and gases in a same cross section is constant and decreases linearly from the velocity of mixture at the rear part of the low-pressure chamber to the velocity of grenade;

g. The recoil of the barrel is not taken into account;

h. The friction between mixture and walls of barrel is neglected.

3. Mathematical Model

The equations and relations of the mathematical model are presented on chambers [5].

The equations and relations for the high-pressure chamber (first chamber) are following:

a. Equations and relations, which characterise the propellant burning and the gases forming:

- the burning rate law

$$u_1 = Ap_1^{\nu}; \tag{1}$$

- the gases forming law

$$\psi_1 = \chi z_1 + \chi\lambda z_1^2 + \chi\mu z_1^3; \tag{2}$$

- the variation of velocity of the relative thickness of powder elements

$$\frac{dz_1}{dt} = \frac{Ap_1^{\nu}}{e_0}; \tag{3}$$

- the burning rate of propellant

$$\frac{de_1}{dt} = u_1; \tag{4}$$

b. Relation of gases pressure

$$p_1 = \frac{f_a \omega_a + f\omega(\psi_1 - \eta)}{W_{0,1} - \frac{\omega}{\delta}(1 - \psi_1 - \xi) - \alpha\omega(\psi_1 - \eta) - \alpha_a \omega_a}; \quad (5)$$

c. Variation of the velocity of flown gases fraction through the holes in the second chamber

$$\frac{d\eta}{dt} = \frac{Q_s}{\omega} = \frac{(1-\varepsilon)Q_m}{\omega}, \quad (6)$$

where

$$\varepsilon = \frac{1 - \xi - \psi_1}{1 - \xi - \eta};$$

d. Variation of the velocity of crossed particles fraction through the holes in the second chamber

$$\frac{d\xi}{dt} = \frac{Q_p}{\omega} = \frac{\varepsilon Q_m}{\omega}. \quad (7)$$

e. Relation for the critical pressure

$$p_{1,crit} = p_1 \left(\frac{2}{\gamma_m + 1}\right)^{\frac{\gamma_m}{\gamma_m - 1}}, \quad (8)$$

where

$$\gamma_m = \frac{(1-\varepsilon)c_p + \varepsilon c_{pr}}{(1-\varepsilon)c_v + \varepsilon c_{pr}}.$$

The equations and relations for the low-pressure chamber (second chamber) are following:

a. Equations and relations, which describe the processes in the second chamber:

- the burning rate law

$$u_2 = Ap_2^{\nu}; \quad (9)$$

- the gases forming law

$$\psi_2 = \chi z_2 + \chi\lambda z_2^2 + \chi\mu z_2^3; \quad (10)$$

- the variation of velocity of the relative thickness of powder elements

$$\frac{dz_2}{dt} = \frac{Ap_2^{\nu}}{e_0}; \quad (11)$$

- the burning rate of propellant

$$\frac{de_2}{dt} = u_2; \quad (12)$$

b. Relation of gases pressure

$$p_2 = \frac{f\omega\xi\psi_2 + f\omega\eta - (\gamma_m - 1)\varphi m_{gr}\frac{v_{gr}^2}{2}}{W_{0,2} - \frac{\omega}{\delta}\xi(1-\psi_2) - \alpha\omega(\eta + \xi\psi_2) + s\ell}; \tag{13}$$

c. Equation of the translating motion of grenade

$$\frac{dv_{gr}}{dt} = \frac{p_2 s}{\varphi m_{gr}}, \tag{14}$$

where

$\varphi = 1 + k_2 + k_3 + k_4 + k_5$;

d. Equation of grenade velocity

$$v_{gr} = \frac{d\ell}{dt}; \tag{15}$$

e. Relation for the pressure at the rear part of the second chamber

$$p_{2,f} = p_{2,gr}(1 + \frac{\omega'}{2\varphi_1 m_{gr}}) - \frac{\rho_{\omega'} u_f^2}{2}(\frac{v_{gr}}{u_f} - 1), \tag{16}$$

where:

$$p_{2,gr} = \frac{p_2 + \frac{\rho_{\omega'} u_f^2}{6}(\frac{v_{gr}}{u_f} - 1)}{(1 + \frac{\omega'}{3\varphi_1 m_{gr}})}; \ \omega' = \omega(\eta + \xi);$$

$$\rho_{\omega'} = \frac{\omega'}{W_{0,2} + s\ell}; \ \varphi_1 = 1 + k_2 + k_3.$$

Between the critical pressure and pressure at the rear part of the second chamber, the following situations can exist:

a. If $p_{2,f} \le p_{1,crit}$, the debit and the velocity of mixture in the critical section of hole is calculated with the aid of the following relations:

$$Q_m = \varphi_2 p_1 s_{cr}\sqrt{\gamma_m(\frac{2}{\gamma_m + 1})^{\frac{\gamma_m+1}{\gamma_m-1}}\frac{1}{f\tau_{med}}}; \tag{17}$$

$$u_{cr} = \sqrt{\frac{2\gamma_m}{\gamma_m + 1} f\tau_{med}} \; , \tag{18}$$

where

$$\tau_{med} = \frac{T}{T_1};$$

b. If $p_{2,f} \geq p_{1,crit}$, the debit and the velocity of mixture in the critical section of hole are calculated with the aid of the following relations:

$$Q_m = \varphi_2 p_1 s_{cr} \sqrt{\frac{2\gamma_m}{(\gamma_m - 1) f\tau_{med}} \left[(\frac{p_{2,f}}{p_1})^{\frac{2}{\gamma_m}} - (\frac{p_{2,f}}{p_1})^{\frac{\gamma_m+1}{\gamma_m}} \right]} \; ; \tag{19}$$

$$u_f = \sqrt{\frac{2\gamma_m}{(\gamma_m - 1)} f\tau_{med} \left[1 - (\frac{p_{2,f}}{p_1})^{\frac{\gamma_m-1}{\gamma_m}} \right]} \; . \tag{20}$$

These relations allow studying the variation of gases pressure in both chambers and grenade velocity versus displacement inside the barrel, during of powder burning.

4. Interor Ballistic Software

In order to obtain the variation of gases pressure in both chambers and grenade velocity versus displacement, after finishing of powder burning, the mathematical model is completed with following relations [1], [7], [8]:

$$p_2 = p_{2,k} (\frac{\ell' + \ell_k}{\ell' + \ell})^{\theta+1} \; ; \tag{21}$$

$$v_{gr} = v_{\lim} \sqrt{1 - (\frac{\ell' + \ell_k}{\ell' + \ell})^{\theta} (1 - \frac{v_{gr_k}^2}{v_{\lim}^2})} \; , \tag{22}$$

where:

$$\ell' = \ell_{0,2}(1 - \alpha\Delta_2\eta) \; ; \; \ell_{0,2} = \frac{W_{0,2}}{s} \; ; \; s = n_s d^2 \; ;$$

$$\Delta_2 = \frac{\omega}{W_{0,2}} \; ; \; v_{\lim}^2 = \frac{2f\omega}{\theta\varphi m_{gr}} \; ; \; \theta = \gamma - 1 \; .$$

Also, in order to obtain the variation of gases pressure in both chambers and grenade velocity versus time, it is used following relation [1], [7], [8]:

$$t = t_k + \int_{\ell_k}^{\ell} \frac{1}{v_{gr}} d\ell \cong t_k + \sum_i \frac{\frac{1}{v_{gr_i}} + \frac{1}{v_{gr_{i+1}}}}{2} \left(\ell_{i+1} - \ell_i \right). \tag{23}$$

The solving of the system of differential and algebraic equations, which compose the mathematical model, is done with the following initial conditions:

$$t = 0; \ell = 0; v_{gr} = 0; z_1 = 0; z_2 = 0; \eta = 0; \xi = 0 .$$

On the basis of mathematical model, interior ballistics software of numerical integration was elaborated, using the fourth order *RUNGE-KUTTA* method. This software allows studying the variation of gases pressure in both chambers and grenade velocity versus displacement inside the barrel and versus time.

5. Resuls and Conclusions

In Fig. 2 and Fig. 3 it is presented the variation of gases pressure versus displacement and versus time, obtained with the aid of the interior ballistics software, for an extant grenade launcher with high-low pressure chambers.

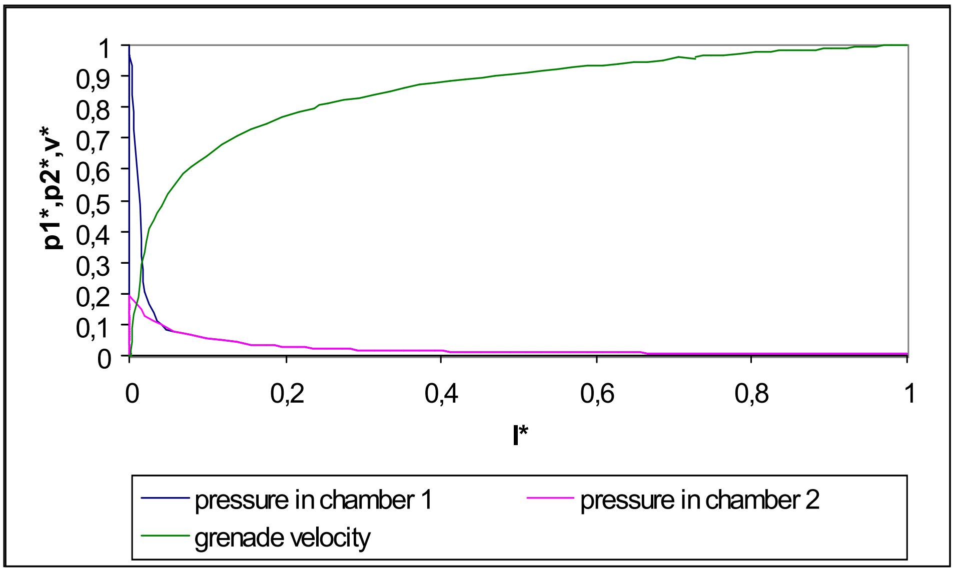

Fig. 2 Variation of gases pressure and grenade velocity versus displacement

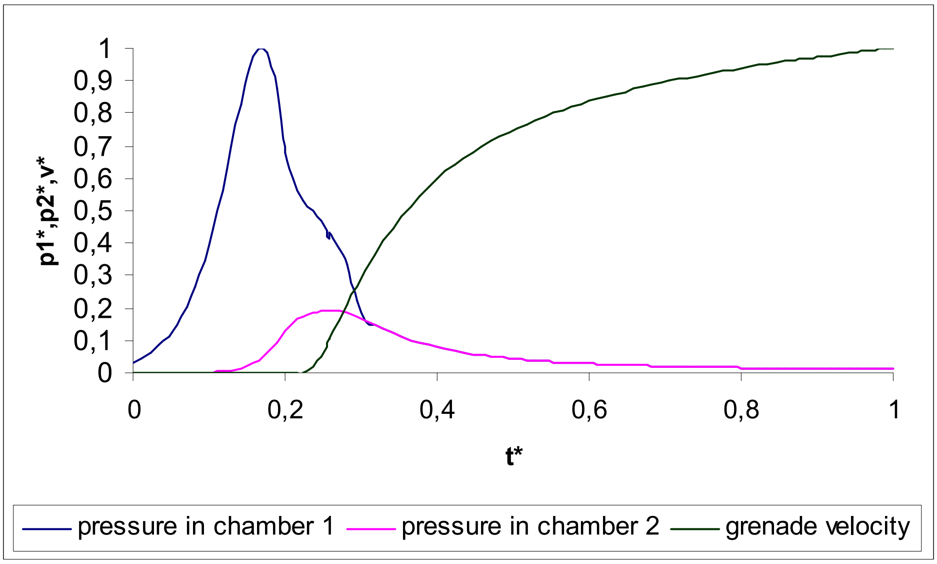

Fig. 3 Variation of gases pressure and grenade velocity versus time

In these diagrams the following notations are used:

$$t^* = \frac{t}{t_g};\ p_1^* = \frac{p_1}{p_{1\max}};\ p_2^* = \frac{p_2}{p_{1\max}};\ v^* = \frac{v_{gr}}{v_{gr_g}};\ \ell^* = \frac{\ell}{\ell_g}. \qquad (24)$$

Besides the study of gases pressure and grenade velocity versus displacement and versus time variation, the elaborated software allows to study the influence of the variation of different parameters on main ballistic magnitudes. In this way, it is possible to study the influence of the propellant nature, the ratio of chambers volumes, the number and the dimensions of holes on maximum pressure in both chambers and on grenade muzzle velocity.

In order to study the influence of propellant nature were used values of force and covolume for two powders: P-55 and P-60, having same mass of powder charge $\omega = 0{,}60 \quad g$.

The results concerning the influence of nature of powder on main ballistic magnitudes are presented in Table 1.

Table 1

Type of powder \ Magnitudes		$p_{1,\max}$ [MPa]	$p_{2,\max}$ [MPa]	v_{gr_g} [m.s^{-1}]
P-55	Computation	138,63	26,42	86,85
	Experiment	-	29,80	82,40
P-60	Computation	165,35	27,45	88,83
	Experiment	-	30,96	84,78

On the bases of experimental data and calculation results from Table 1 can be concluded that exist a good accordance between practice and theory. Forward, the powder P-55 will be used in all the studies.

The influence of ratio between chambers volumes is shown in the Table 2.

Table 2

Magnitudes / Values of ratio	$p_{1,\max}$ [MPa]	$p_{2,\max}$ [MPa]	v_{gr_g} [m.s^{-1}]
8,95	138,626	26,4204	86,85
0,58	147,636	26,425	86,85

For the determination of influence of number and surface of holes, was modified the surface of all holes. The results of this simulation are presented in the Table 3.

Table 3

Surface of holes [m^2]	$p_{1,\max}$ [MPa]	$p_{2,\max}$ [MPa]	v_{gr_g} [m.s^{-1}]
$1,53*10^{-5}$	138,63	26,42	86,85
$1,63*10^{-5}$	118,35	27,87	89,49
$1,73*10^{-5}$	99,576	29,189	92,36

The choice of suitable characteristics of ballistic system with high-low pressure chambers depends on concrete technico-tactical characteristics of these ballistic systems.

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