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Geometric Coefficients Modifications of Surface Non-Treated Seven-Perforated Nitrocellulose Powder

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Abstract:

Calculating of the interior ballistics characteristics using seven-perforated nitrocellulose powder in cartridge assemblies can be used in special techniques and in special projectile sets. Accuracy of interior ballistics characteristics calculations influences construction solutions of special techniques and ammunition; main utilization is in armed forces special techniques and ammunition for country defence. Originally derived relations make geometric coefficients solution of non-treated seven-perforated powder more accurate and easier to use.

Keywords:

Interior ballistics, interior ballistics characteristics, ammunition, gun, nitrocellulose powder.

1. Preparing Gun and Ammunition

Using seven-perforated nitrocellulose powder in substantial range different calibres cartridge sets is a long-term common routine, which has been a worldwide practice of ammunition producers for about 80 years.

In technical literature the powder combustion process description differs author to author and is not always practically applicable. In a factory, which produces heavy artillery weapons, it is a common practice to substitute seven-perforated grains by single-perforation grain in interior ballistic computations using conversion of its weight by means of a specific coefficient.

We have conducted an experiment when a total of 18 shots from a fully charged 122 mm H D-30 gun using projectile filled with an inert charge was shot. The barrel of the gun was equipped with six strain gauges, as follows [1, 2]:

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- 1 piece on the chamber,
- 1 piece just beyond the transition cone,
- 1 piece in a place where the bullet is supposed to be in the time of reaching the maximum pressure and other 3 pieces uniformly placed towards the end of the barrel.

Fig. 1 122 mm H D-30 gun provided with strain gauges

Fig. 2 Powder charge

Powder charge contained units relatively to the total weight of the charge as follows:

- black powder 0.73 %,

- locking powder 1.93 %,
- single-perforation nitrocellulose powder 5.07 %,
- seven-perforated nitrocellulose powder 92.27 %.

Surface of nitrocellulose powder was not treated and the test samples were chosen from an ordinary production lot, stored under normal conditions in an explosives magazine.

Non-treated seven-perforated powder is known by its expected progressive way of combustion contrary of the single-perforation powder (neutral combustion) or non-treated spherical powder (digressive combustion). This combustion characteristic is given by virtual burning area of a grain which raises, reduces or theoretically does not change.

We suppose simultaneous ignition of the whole surface of all powder grains in a charge by ideal powder combustion. We also suppose that grains are perfectly identical, homogeneous, in no contact with either each other, or the cartridge wall. Combustion spreads uniformly and vertically to the grain surface in any moment of combustion.

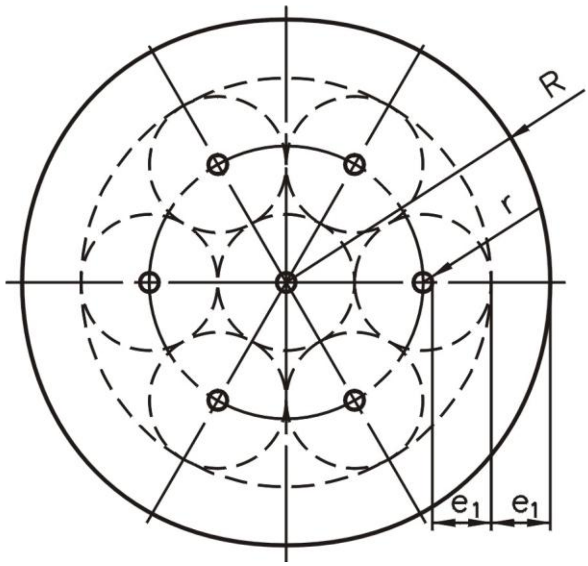

Fig. 3 Basic form of seven-perforated grain (dimensions of the seven-perforated powder)

In reality one can hardly imagine that a powder charge ignited from one point through an igniter – in most cases from the bottom of cartridge – ignites all of approximately 5000 pieces of seven-perforated powder grains which are freely poured in the same charge or partial charges. In addition, specific charge was connected to the single-perforation powder grains array.

From the powder charge adjustment it is obvious that ignition of all powder grains will not be simultaneous but successive. The gas is released from all powder grain holes and consequently prospective seven-perforated grain combustion progress will also be problematic. In addition, this process depends on instantaneous pressure, temperature and chemical composition of the powder. In literature, e. g. [3] or [4], one can find out a hypothesis of an accurate adjustment and proportions of each geometric dimension in relative, exactly determined ratios of particular diameters (inner hole diameter and outer diameter) and length of the grain. Figs. 4 and 5 – dark area shows differences between proportions of grain by [3] and [4] and a real diameters grain.

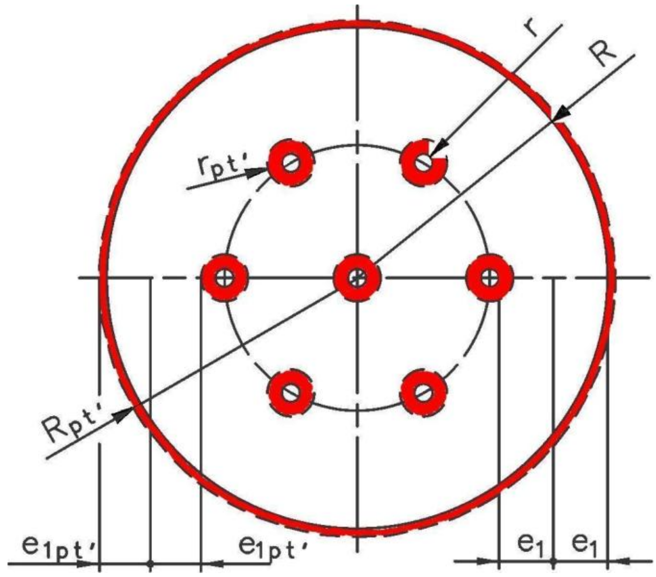

Fig. 4 Dimensions of the grain by [3]: $R_{pt'}$, $r_{pt'}$, $e_{1pt'}$

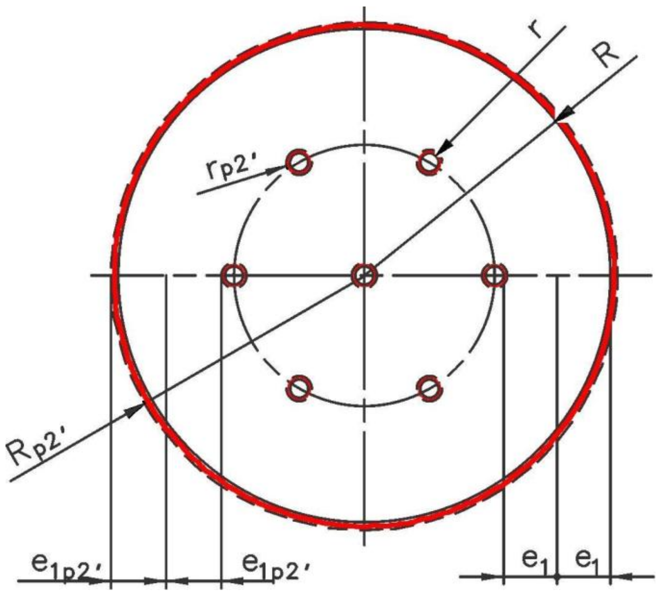

Fig. 5 Dimensions of the grain by [4]: $R_{p2'}$, $r_{p2'}$, $e_{1p2'}$

During our experiment the proportions of an average of 10 grains of each kind of powder had been chosen. Measurements revealed that the calculations introduced in the actual literature are based on the proportions of production instruments. Real proportions of seven-perforated grain are very different from the expected ones which has mostly been caused by the deformations the grain is exposed to during the process of drying.

2. Calculation Procedure of Coefficient *κ*

For our interior ballistic characteristics calculation, the following data were used:

- own measurements of powder grains weight and size,
- non-treated seven-perforated powder thermodynamic characteristics calculation elaborated by the producer,
- Professor Sluchocky's methodology [5], [6].

As stated before, the hardest problem to be faced was to set the non-treated seven-perforated powder grain geometric shape coefficient, especially geometric coefficient κ.

For the necessary calculations of interior ballistic parameters, the following technique of geometric coefficient κ determination was chosen under these conditions:

- whole powder charge was considered as non-treated seven-perforated powder charge,
- non-treated seven-perforated powder grain relative burnt thickness – parameter) z - when e_1 portion is burnt out, it will be $z = 1$ and this value will not raise any more,
- variable relative amount of burnt non-treated seven-perforated grain – parameter ψ – when e_1 portion is burnt out, it will be $\psi = 1$ and this value will not change any more,
- Even in the case of the known fact that, though the e_1 portion of non-treated Seven-perforated grain has been burnt, burning is not finished because the grain splits into 12 triangular prisms (6 outer and 6 inner ones), those burn in a degressive way.

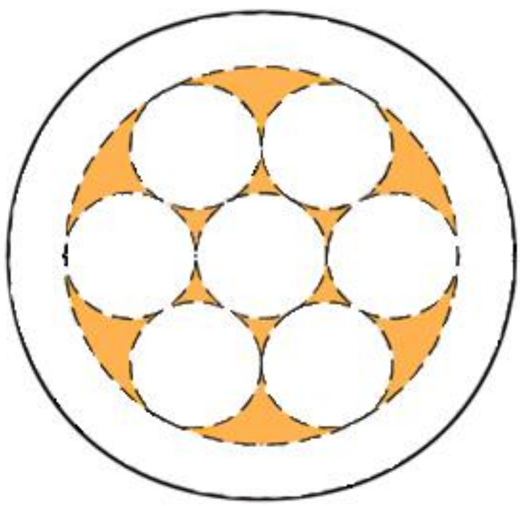

Fig. 6 Inner triangular prisms and outer triangular prisms

For geometric coefficient κ calculation, we can apply the following equation [5]

$$\kappa = \frac{S_0}{V_0} e_1 \tag{1}$$

and transform it considering the areas and volumes of split grains as follows [1], [2]

$$\kappa = \frac{S_0 + S_1 + S_2}{V_0 + V_1 + V_2} e_1 , \tag{2}$$

where:

e_1 is the characteristic thickness of a powder grain,

S_0 is the initial surface area of a powder grain,

S_1 is the surface area of inner triangular prisms, after the grain split when an e_1 portion was burnt out,

S_2 is the surface area of outer triangular prisms, after the grain split when an e_1 portion was burnt out,

V_0 is the initial volume of a powder grain,

V_1 is the volume of inner triangular prisms, after the grain split when an e_1 portion was burnt out,

V_2 is the volume of outer triangular prisms, after the grain split when an e_1 portion was burnt,

and where the surface area $S_{1,2}$ of inner and outer triangular prisms has been calculated from equation

$$S_{1,2} = \left[2a_{1,2}^2 \frac{\sqrt{3}}{4} + 3a_{1,2}^2 (2L - 2e_1) \right] 6 \tag{3}$$

and where the volume $V_{1,2}$ of inner and outer triangular prisms has been calculated using the following equation

$$V_{1,2} = \left[a_{1,2}^2 \frac{\sqrt{3}}{4} (2L - 2e_1) \right] 6 . \tag{4}$$

Regarding the complex form of inner and outer prisms, we can determine the prism bases for surface area and volume calculations to be of an equilateral triangular shape having the length of edges as follows:

- auxiliary equilateral triangular height calculation – length of its edge:

$$a' = 2r + 2e_1 , \tag{5}$$

where

r is the inner grain holes radius.

Then

$$v' = \frac{\sqrt{3}}{2} a' . \tag{6}$$

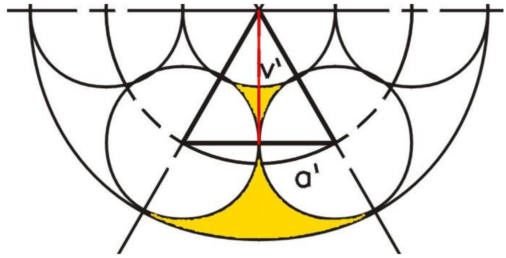

Fig. 7 Scheme for calculation of auxiliary equilateral triangular

Design procedure is as follows:

- inner triangular prisms base height calculation

$$v_1' = v' - (r + e_1)\,, \tag{7}$$

- outer triangular prisms base height calculation

$$v_2' = (3e_1 + 3r) - v'\,, \tag{8}$$

- inner triangular prisms base edge calculation

$$a_1' = \frac{2}{\sqrt{3}} v_1'\,, \tag{9}$$

- outer triangular prisms base edge calculation

$$a_2' = \frac{2}{\sqrt{3}} v_2'\,. \tag{10}$$

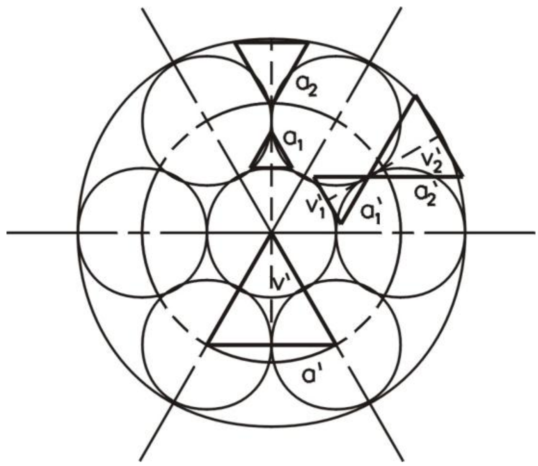

Fig. 8 Scheme for calculation procedure of triangles

Then

$$a_1 = a_1' k_a\,, \tag{11}$$

$$a_2 = a_2' k_a\,, \tag{12}$$

- calculation procedure of k_a

$$k_a = \frac{S_b}{S_{Ra}} , \tag{13}$$

where

k_a in both cases is a coefficient representing modifications of triangular prisms base edges obtained as a sum of burnt surface (free) areas S_b in circles of radius r_a and S_{Ra} area (circle of radius R_a area) ratio,

S_b is a sum of burnt (free) areas

$$S_b = \pi r_a^2 , \tag{14}$$

S_{Ra} is a Ra radius circle area

$$S_{Ra} = \pi R_a^2 , \tag{15}$$

where is

$$R_a = R - e_1 , \tag{16}$$

$$r_a = r + e_1 . \tag{17}$$

where

R is the non-treated seven-perforated grain outer radius before ignition,

r is the inner radius of grain holes.

Value of k_a coefficient is invariable for any non-treated seven-perforated grain proportions.

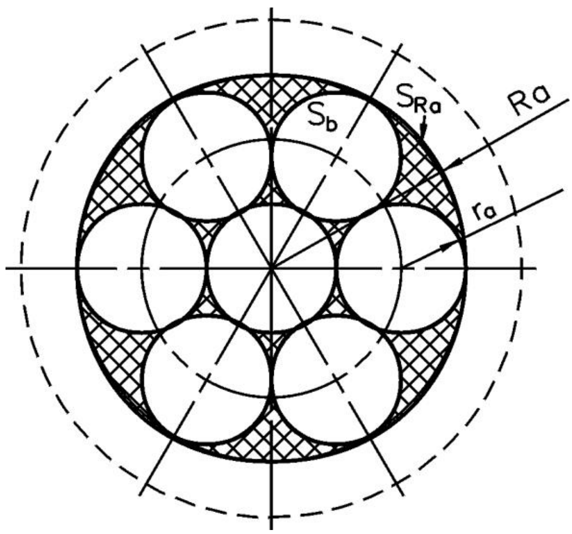

Fig. 9 Scheme for calculation procedure of k_a

This modified succession for geometric coefficient κ calculation results in the time dependent pressure curve shown in Fig. 10. Curve represented by the integrity line shows measured time dependent pressure calculated from strain gauge measured values, successively measured on each strain gage behind a moving projectile during experimental shots.

Note:
Barrel deformations measured by strain gauges were recalculated into the pressure of propellant gases $p_{\varepsilon i}$ by means of the following equations [2]:

$$p_{\varepsilon i} = C\varepsilon_i \,,$$

where

$C = 0.5E[(D/d)^2 - 1]$,
E = 210 000 MPa – is the modulus of elasticity of the barrel material,
D_i – is the outer diameter of the barrel at the measuring place,
d_i – is the internal diameter of the barrel in grooves at the measuring place,
ε_i – is the tangential relative deformation at the measuring place.

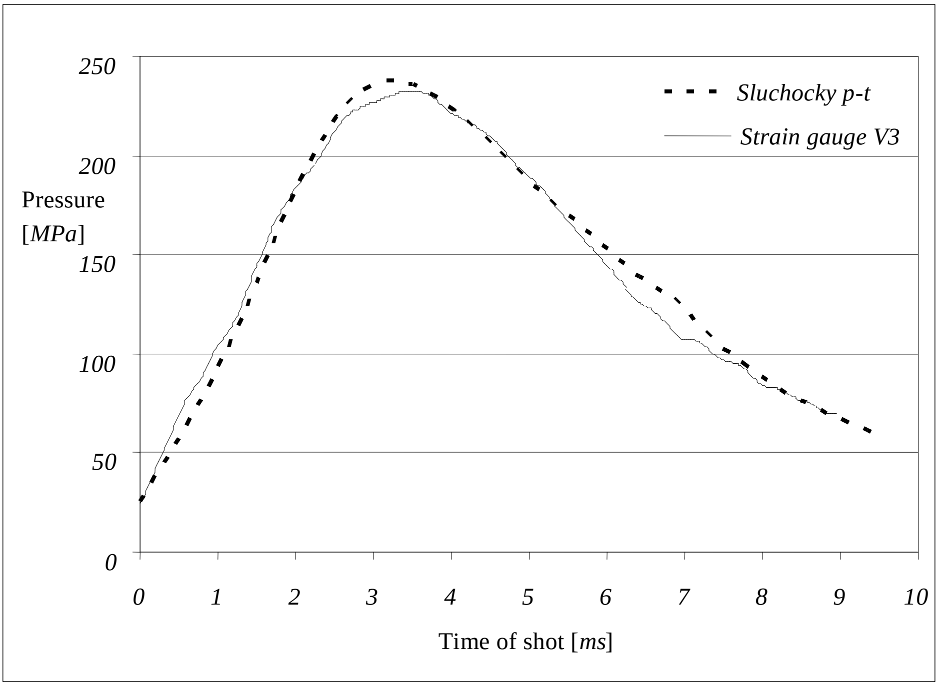

Fig. 10 Time dependent pressure curves

3. Conclusion

Experimental shooting results have shown that the author's approach to the theoretical basis for calculating the geometric coefficient κ can be applied in practice.

Calculations and practical shooting experiment was conducted on only one type of surface-non-treated seven-perforated nitrocellulose powder. In the next period it is necessary to verify the adopted theoretical conclusion of calculating the geometrical characteristic κ also for another type and size of non-treated seven-perforated nitrocellulose powder and with another weapon system.

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