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CONTRIBUTION ON THE GEOMETRIC COEFFICIENTS MODIFICATIONS OF SURFACE NON-TREATED SEVEN-PERFORATED NITROCELLULOSE POWDER

Calculating of interior ballistics characteristics using seven-perforated nitrocellulose powder in cartridge assemblies can be used in special techniques and in special projectile sets (cartridges). 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.

Key words: interior ballistics, interior ballistics characteristics, ammunition, gun, nitrocellulose powder.

Introduction

Using seven-perforated nitrocellulose powder in substantial range different calibers 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 literature, e. g. [4] or [5], 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.

Fig. 1. Seven-perforated nitrocellulose powder

During our experiment the proportions of an average of 30 grains of each kind of powder had been chosen. Measurements revealed that the calculations introduced in the actual literature [4] or [5] are based on the proportions of production instruments. Real proportions of seven-perforated grain are very different from the expected ones which have mostly been caused by the deformations the grain is exposed to during the process of drying.

Calculation procedure of coefficient κ

The system of equations for the time argument t (in professor Sluchocky's methodology) is the most comprehensive and least formally distinct from physical equations, from which the derivation is based. The final system of equations of internal ballistics used equation of production of power gases:

$$\psi = \kappa \cdot z \cdot \left(1 + \lambda \cdot z\right) \tag{1}$$

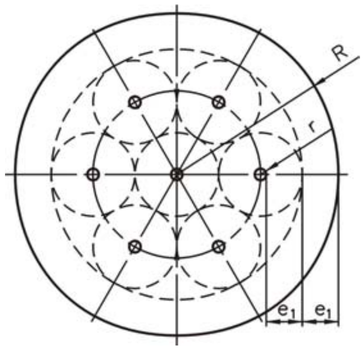

Fig. 2. Basic form of seven-perforated grain (dimensions of the seven-perforated powder): „R“ is the grain outer radius, „r“ is the inner grain holes radius, „e_1“ is the characteristic thickness of a grain

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 [8], [9], where geometric coefficients λ and μ were set value 0.

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,

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– 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.

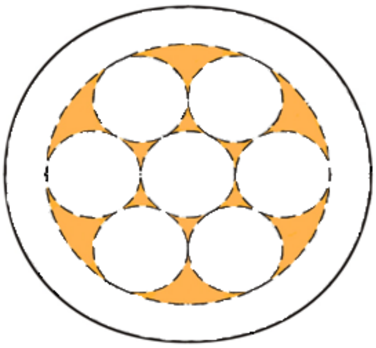

Fig. 3. Inner triangular prisms and outer triangular prisms

Mathematical methods of calculating the adjustment coefficient κ

For geometric coefficient κ calculation, we can apply the following equation [8]

$$\kappa = \frac{S_0}{V_0} \cdot e_1 \tag{2}$$

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

$$\kappa = \frac{(S_0 + S_1 + S_2)}{(V_0 + V_1 + V_2)} \cdot e_1, \tag{3}$$

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 out

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

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

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

$$V_{1,2} = \left[a_{1,2}^2 \cdot \frac{\sqrt{3}}{4} \cdot (2L - 2e_1) \right] \cdot 6. \tag{5}$$

Determination of the footprint of inner and outer triangular prisms

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:

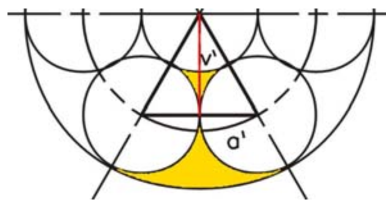

Fig. 4. Scheme for calculation of auxiliary equilateral triangular

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

$$a' = 2 \cdot r + 2e_1, \tag{6}$$

where r is the inner grain holes radius

then

$$v' = \frac{\sqrt{3}}{2} \cdot a'. \tag{7}$$

Design procedure is as follows:

• inner triangular prisms base height calculation

$$v_1' = v' - (r + e_1), \tag{8}$$

• outer triangular prisms base height calculation

$$v_2' = 3 \cdot (r + e_1) - v', \tag{9}$$

• inner triangular prisms base edge calculation

$$a_1' = \frac{2}{\sqrt{3}} \cdot v_1', \tag{10}$$

• outer triangular prisms base edge calculation

$$a_2' = \frac{2}{\sqrt{3}} \cdot v_2'. \tag{11}$$

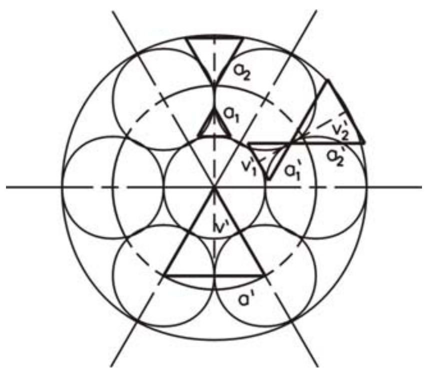

Fig. 5. Scheme for calculation procedure of triangles

Then

$$a_1 = a_1' \cdot k_a, \tag{12}$$

$$a_2 = a_2' \cdot k_a, \tag{13}$$

- calculation procedure of k_a:

$$k_a = \frac{S_b}{S_{Ra}}, \tag{14}$$

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

$$S_b = \pi \cdot r_a^2, \tag{15}$$

S_{Ra} is a Ra radius circle area

$$S_{Ra} = \pi \cdot R_a^2, \tag{16}$$

where is

$$R_a = R - e_1, \tag{17}$$

$$r_a = r + e_1, \tag{18}$$

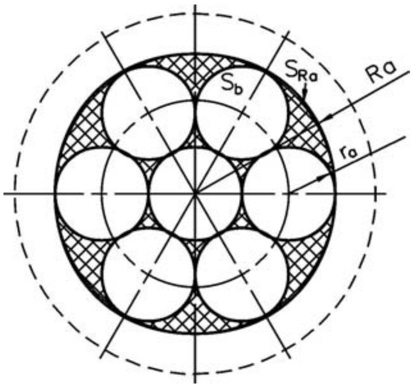

Fig. 6. Scheme for calculation procedure of k_a

and finally:

$$a_1 = 0.658 \cdot (r + e_1), \tag{19}$$

$$a_2 = 1.139 \cdot (r + e_1). \tag{20}$$

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

Practical application in the calculations

This modified succession for geometric coefficient κ calculation results in the time dependent pressure curve shown in Figure 7:

– curve represented by the solid (black) line shows measured time dependent pressure calculated from strain gauge measured and calculated mean values, successively measured on each strain gage behind a moving projectile during experimental shots,

– curve represented by the dash dot (brown) line shows measured time dependent pressure calculated by previously used approach for geometrical characteristic κ by (2):

$$\kappa = \frac{S_0}{V_0} \cdot e_1,$$

– curve represented by the broken (blue) line shows measured time dependent pressure calculated by new author's approach for geometrical characteristic κ by (3):

$$\kappa = \frac{(S_0 + S_1 + S_2)}{(V_0 + V_1 + V_2)} \cdot e_1.$$

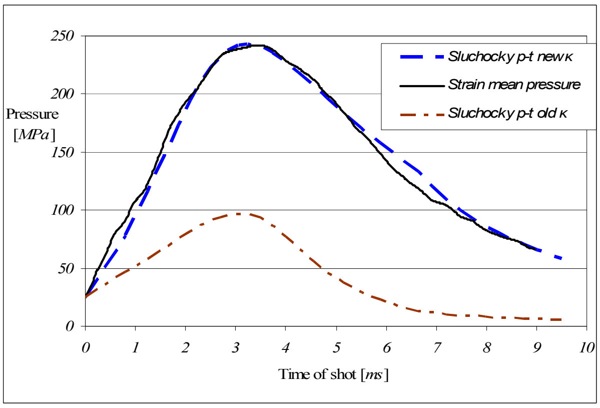

Fig. 7. Time dependent pressure curves

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.

The results show that the author's approach to the calculation of the geometrical characteristic κ values has approached the theoretical calculation of powder gas pressure values actually measured during the shooting of the experiment, which are represented in Figure 7 as the calculated mean. This improvement is apparent throughout the pressure range of powder gas, especially at maximum pressure and muzzle pressure.

Calculations and practical shooting experiment results have been conducted with only one type of surface-non-treated seven-perforated nitrocellulose powder. In the next period it is desirable 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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К вопросу о модификации геометрических параметров поверхностно-необработанного пироксилинового пороха с семью каналами

Расчет характеристик внутренней баллистики при использовании пироксилинового пороха с семью каналами в сборном патроне может быть применен для специальной техники и специальных снарядов (патронов). Точность расчета характеристик внутренней баллистики влияет на принятие конструктивных решений для специальной техники и военного снаряжения; основная область применения – оборонная специальная техника и военное снаряжение вооруженных сил. Полученные зависимости дают более точные и простые в применении геометрические характеристики необработанного пороха с семью каналами.

Ключевые слова: внутренняя баллистика, характеристики внутренней баллистики, военное снаряжение, оружие, пироксилиновый порох.

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МОДЕЛИРОВАНИЕ ГАЗОДИНАМИЧЕСКИХ ПРОЦЕССОВ В СИСТЕМАХ ОХЛАЖДЕНИЯ ГАЗОПЕРЕКАЧИВАЮЩИХ АГРЕГАТОВ

Рассматривается методика расчета температурного режима внутри шумотеплозащитного кожуха газоперекачивающего агрегата. Методика основана на решении пространственных уравнений газовой динамики и позволяет учесть местоположение отдельных модулей агрегата внутри кожуха. Верификация методики осуществлена сравнением расчетов с результатами экспериментов.

Ключевые слова: газоперекачивающий агрегат, охлаждение, математическая модель, метод крупных частиц.

Современные газоперекачивающие агрегаты (ГПА) – сложные технические объекты. Так, в типовую конструкцию ГПА (рис. 1, [1]) входят газотурбинный двигатель с улиткой *1*, воздуховоды *2*, по которым в кожух шумотеплоизоляционный (КШТ) *8* подается охлаждающий газ; *3* – пол КШТ, ящик *4* агрегата зажигания, фундамент рамы двигателя *5*, защитный экран *6*, улитка *7* выхлопного устройства ГПА.

Надежная работа ГПА в значительной степени определяется температурным режимом внутри КШТ газоперекачивающего агрегата. Предельная температура воздушной массы внутри КШТ составляет 120…130 °С. Превышение этой температуры приводит к перегреву конструкции газотурбинной установки (ГТУ) и к необходимости ее останова. Регулирование температуры внутри КШТ обеспечивается изменением массоприхода воздуха, нагнетаемого из окружающей среды в объем КШТ по воздуховодам *2*. Анализ показывает, что массоприход нагнетаемого воздуха не единственный способ регулирования температуры внутри КШТ. Важными представляются и мероприятия, связанные с компоновкой в составе ГПА воздуховодов *2*, улиток *1*, *7* и др. Из-за высокой стоимости экспериментальных исследований, позволяющих установить влияние перечисленных факторов на температурный режим внутри КШТ, для решения задачи представляется целесообразным использовать технологию математического моделирования.

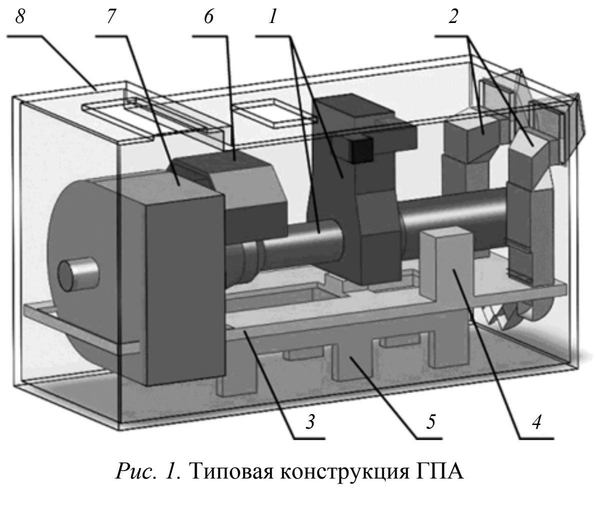

Рис. 1. Типовая конструкция ГПА

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