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The Influence of Variance of Bullet Weight to Muzzle Velocity of Bullet

Abstract

The goal of this work is showing the influence of variance of bullet to muzzle velocity. Ballistics is as a science very complicated, so it was divided into inner and external ballistics. All of features of ballistics' are very complicated and they all influence each other. The problematic of counting all of these phenomena's is very comprehensive and we are not able to make one big theory of all of these features and show how they influence the bullet, because each single change of parameter can cause different results in different measured size.

In my project I want to express how weight of bullet and its variance influences the muzzle velocity of bullet. There are so many factors that influence the muzzle velocity and on the other hand there are many factors that are influenced by muzzle velocity. Here it is greatly shown how inner and external ballistics co-operate together during fire.

In theoretical part I try to explain some facts about shot 7,62mm x 43 and try to give some basic information about this bullet. Then I state some basic inner and external ballistic features and show how they influence the muzzle velocity. Despite the fact that this work is mainly about variance of bullet weight I can not forget to state others phenomenoms at least in small measurement. Afte that I make equation with all parameters influencing muzzle velocity and then, due to characteristics of weapon and weapon system I calculate it and try to say how muzzle velocity is influenced by variance of bullet weight.

In practical part, that is in the middle of theoretical one I make weight determination process to state weigts of shots to be able to count equations of muzzle velocities. I tis very difficult to find the line between the theoretical part and practical part because they are closely connected.

Due to facts that understanding of all ballistics features of this project is difficult I try to explain the facts appearing in this work in simple ways.

Keywords: bullet, ballistics, charging conditions, muzzle velocity, bullet weight, equation, calculations

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INTRODUCTION

Nowadays we live in a world that is on a high level of industry and all gadgets of our everyday life are very complicated, because they are projected to work efficiently and effectively. Even in military we try to make weapons more and more effective so we are able to defend our land better. During the years weapon industry has been changing and trying to make weapons and weapon system better. Each single parameter must be counted correctly and mistakes and deviations must be correctly eliminated and in case of having some disagreements, they must be eliminated. Weapon must be designed and constructed in agreement with security and ballistic theorems. However, we are not always able to manufacture all of components that are connected to weapon system in a same weight or other parameter. Despite the fact that methods and technologies are on a very high level there will always be small differences with values that we calculate with and values that are constructed. At first it may look negligibly but weapon system is complicated summary of many parts and even small deviations of each of them may cause disability of weapon system. This work is about showing, how one of these parameter that may look on the first sight as not affecting, can affect very important size of weapon system.

Ballistics as a science is divided into inner and external ballistics as a reason of better understanding. Both, inner and external ballistics, exist together and they affect each other, but some of their features can be easily told while looking at them just as a part of one of them. Inner ballistics deals with features as reloading conditions, burning of gas powder etc. and external ballistics deals with features as range, impact of bullet or accuracy.

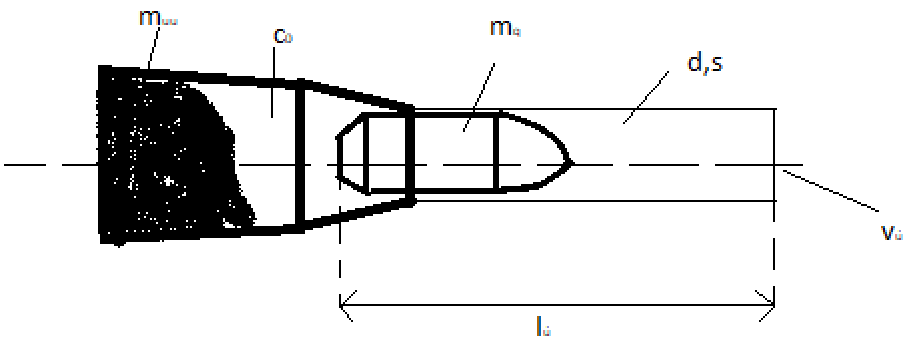
From the view of inner ballistics, we look at muzzle velocity as how it is influenced, and from the view of external ballistics, we can talk about how muzzle velocity affects other parameters. This fact just emphasizes how important it is to understand all facts.

1. IMPORTANCE OF VARIANCE OF BULLET WEIGHT

Muzzle velocity of bullet is the speed of bullet in the moment when bullet is on the end of barrel. It influences the distance of shot, the impact on the target and also accuracy. These factors are very important in military ballistics. On the other hand, there are also features influencing the muzzle velocity. From category of inner ballistics features we can state the weight of bullet, length of barrel, weight of powder, other powder´s characteristics, calibre etc. To completely understand to all features, let´s see the equation of muzzle velocity.

To understand the importance of variance of bulet weight we have to know and understand features of weapon system and how they affect muzzle velocity. By increasing value of any of these parameters we can increase or decrease the muzzle velocity.

We also can not forget to think about safety because each weapon system must be in order to rules of usage. Despite the fact that in theoretical thinking weapon system may work, in does not necessarily mean that it is safe etc.



Picture 1 Ballistic drawing of barrel and bullet

1.1 Parameters infuencing muzzle velocity

- f = powder force
- s = cross-section area of the bore barrel
- α = covolume of powder gases
- δ = powder mass density
- m_q = projectile mass
- m_ω = powder charge mass
- χ = coefficient of enlargement combustion chamber volume
- k_ϕ = coefficient of passive resistances against projectile motion in the barrel
- c_0 = initial volume of combustion chamber
- $l_ú$ = barrel length
- $v_ú$ = projectile muzzle velocity
- I_k = total impulse powder gases pressure
- K_c = ratio of specific heat of gases at constant pressure and volume

Powder force is the theoretical work, which would be done by explosion of 1kg of gun powder in normal pressure by increaing from 273K to explosive temperature. Powder force is often used to characterise effect of explosive by many other characteristics concurrently. The value of powder force is denoted in J/kg.

Cross-section area of the bore barrel is denoted in m^2.

Covolume of powder gases is the lowest volume, which by given pressure assumes the moleculas of gun powder gases of 1kg of gun powder. Values of covolume of powder gases are pinpointed experimentally in manometric bomb. The value of covolume of powder gases is denoted in m^3/kg.

Powder mass density is the weight of volume ammount by temperature of 15°C and atmospheric pressure. The value of powder mass density is denoted in kg/m^3.

Projectile mass is denoted in kg.

Powder charge mass is denoted in kg.

Coefficient of enlargement combustion chamber volume affects by given starting volume of combustion chamber the length of combustion chamber and also the length of round. By small value of coefficient of enlargement combustion chamber volume it may occur the longer bullet, that may mean lower cadence of weapon. By big value of coefficient of enlargement combustion chamber volume it may occur that taper part can be ttriioned. The value of coefficient of enlargement combustion chamber volume is denoted without unit.

Coefficient of passive resistances against projectile motion in the barrel spans excepting presentated energetical losses also losses of energy of gun powder gases, that by leakage flow away between shot and barrel and also the loss of energy that was used to deformation and amplitude of barrel. Coefficient of passive resistances against projectile motion in the barrel depends on the type of barrel weapon. The value of coefficient of passive resistances against projectile motion in the barrel is denoted without unit.

Initial volume of combustion chamber is the volume of combusting chamber behind the back part of shot lowered by value of cartridge. The value of initial volume of combustion chamber is denoted in m^3.

Barrel length is measured between ground of loaded shot and muzzle of barrel. The value of barrel length is denoted in m.

Total impulse powder gases pressure is important ballistics parameter of powder gases, which can be qualified experimentally, for example in ballistics bomb and it can be used by solving the main task of ballistics. The value of total impulse powder gases pressure is denoted in Pa/s.

Ratio of specific heat of gases at constant pressure and volume is taken as a constnt by solving tasks of ballistics in the whole volume and is affected and also affects with other physical characteristics. The value of ratio of specific heat of gases at constant pressure and volume is denoted without unit.

1.2 The equation of muzzle velocity

The very first step was to import all basic equation to evaluate the final equation of muzzle velocity due to all parameters. Due to fact, that weapon system is very precious, importing all basic equations was very difficult. However, it can show us, how each parameter can possibly influence the muzzle velocity of bullet. However, we mainly aim at variance of bullet weight and all other parameters are counted precisely for used weapon. While calculation of muzzle velocity we used many equations that we need to solve the muzzle velocity.

$$\Delta = \frac{m_\omega}{c_0}$$

$$l_0 = \frac{c_0}{s}$$

$$\theta = \varkappa_c - 1$$

$$\Lambda_ú = \frac{l_ú}{l_0} = \frac{l_ú * s}{c_0}$$

$$\varphi = k_\varphi + \frac{1}{3} * k_{\chi str} * \frac{m_\omega}{m_q}$$

$$k_{\chi str} = \frac{1}{\Lambda_ú} * \left[\Lambda_ú + \left(\frac{1}{\chi} - 1\right) * ln(1 + \Lambda_ú)\right]$$

$$c_q = \frac{m_\omega}{d^3}$$

$$m_{\omega r} = \frac{m_q}{d^3}$$

$$v_{lim} = \sqrt{\frac{2 * f * m_\omega}{\theta * \varphi * m_q}}$$

$$a = f * m_\omega$$

$$j = \varphi * m_q * v_k^2 = \varphi * m_q * \left(\frac{s * I_k}{\varphi * m_q}\right)^2$$

$$b = -\frac{\theta * j}{2 * a} = -\frac{\theta * s^2 * I_k^2}{2 * \varphi * f * m_q * m_\omega}$$

$$k = \frac{j}{a * b} = -\frac{2}{\theta}$$

$$l' = \frac{l_\Delta + l_1}{2}$$

$$l_\Delta = l_0 * \left(1 - \frac{\Delta}{\delta}\right)$$

$$l_1 = l_0 * (1 - \alpha * \Delta)$$

$$A = \frac{a}{s * l'}$$

$$z_m = -\frac{1}{b * (2 - k)} = \frac{\varphi * f * m_q * m_\omega}{s^2 * I_k^2 * (\theta + 1)}$$

$$v_k = \frac{s * I_k}{\varphi * m_q}$$

$$l_k = l' * \left[(1 + b)^k - 1\right]$$

$$v_ú = \sqrt{1 - \left[1 - \left(\frac{v_k}{v_{lim}}\right)^2\right] * \left(\frac{l_1 + l_k}{l_1 + l_ú}\right)^\theta}$$

1.3 Characteristic of 7,62x39 M 43

Soviet military bullet 7,62x39 M 43 was developed by N. M. Jelisarov and B. V. Semin during Second World War. It was introduced to army after war, firstly for self-reloading rifle SKS, then for worldwide known assault rifle AK-47 and machine guns RDP, RPK and RPKS.

This bullet was introduced to armament of armies of China, Finland, Cuba, Nicaragua, Czechoslovakia, states of Near East.

In literature there are inforamtion about ammount of constructed assault rifles AK-47 that are counted between 30 and 100 mil. of pieces. Itis dubtless that this bullet, despite it wasnot used in any world war, but in almost all local conflicts and wars after 2WW, is the bullet that can be placed to bullets with highest ammount of made pieces.

Cartridge of this bullet is mainly made of steel cladded with tombac, steel phosphated and lacquered and also of brass.

Shot of basic conduct is biogival, it´s core is made of steel, and jacket is made of lead and steel. Shots are marked with colour stripes that mean the type of bullet.

Picture 3: Bullets during shooting drills

2. WEIGHT DETERMINATION PROCESS

Importance of precious weight determination is very high because this work is aimed at bullet weight. We used different types of shots and we measured their weight to reach all possible weights of bullet. The variance of values of weight was pretty big despite the fact that shots are constructed in specific laboratories with emphasis to accuracy of prescribed values. Each milligram can cause differences in many parameters influenced by weight of bullet, for example our measured feature- muzzle velocity. During weight determination process we divided bullets into groups with same weights and then we were able to count theoretical values and then, after labouring, experimentally found values.

Picture 3: Weight determination process

Picture 4: Shots sorted due to weight

3. MUZZLE VELOCITY CALCULATIONS

After all parameters characterising gun powder, shot, weapon system etc. were found or calculated, we were able to calculate the values of muzzle velocity due to equations used above.

3.1 CALCULATION NO.1

m_q	0,0093	kg
α	0,0009229	m^3/kg
δ	1600	kg/m^3
χ	1,815	-
k_ϕ	1,1	-
c_0	0,000003521	m3
$l_ú$	0,448	m
I_k	170 000	Pa/s
K_c	1,2437	-
d	0,00762	m
s	0,0000437	m^2
f	1 009 500	J/kg
m_ω	0,0031	kg

$\Delta = \frac{m_\omega}{c_0} =$ 880,431696 kg/m^3

$l_0 = \frac{c_0}{s} =$ 0,080572 m

$\theta = \varkappa_c - 1 =$ 0,2437

$\Lambda_ú = \frac{l_ú}{l_0} = \frac{l_ú * s}{c_0} =$ 0,0000195776

$\varphi = k_\varphi + \frac{1}{3} * k_{\chi str} * \frac{m_\omega}{m_q} =$ 1,16121878

$$\boldsymbol{k_{\chi str}} = \frac{1}{\Lambda_{ú}} * \left[\Lambda_{ú} + \left(\frac{1}{\chi} - 1\right) * \ln(1 + \Lambda_{ú})\right]$$ = 0,550969

$$\boldsymbol{v_{lim}} = \sqrt{\frac{2*f*m_{\omega}}{\theta*\varphi*m_q}}$$ = 1 542,13628775 m/s

$$\boldsymbol{a} = \boldsymbol{f} * \boldsymbol{m_{\omega}}$$ = 3 129,45 J

$$\boldsymbol{j} = \varphi * m_q * v_k^2 = \varphi * m_q * \left(\frac{s*I_k}{\varphi*m_q}\right)^2$$ = 5 110,503805 J

$$\boldsymbol{b} = -\frac{\theta*j}{2*a} = -\frac{\theta*s^2*I_k^2}{2*\varphi*f*m_q*m_{\omega}}$$ =-0,19898541

$$\boldsymbol{k} = \frac{j}{a*b} = -\frac{2}{\theta}$$ = -8,20681165

$$\boldsymbol{l'} = \frac{l_{\Delta}+l_1}{2}$$ = 0,0256784246 m

$$\boldsymbol{l_{\Delta}} = l_0 * \left(1 - \frac{\Delta}{\delta}\right)$$ = 0,0362536609 m

$$\boldsymbol{l_1} = l_0 * (1 - \alpha * \Delta)$$ = 0,0151031882 m

$$\boldsymbol{A} = \frac{a}{s*l'}$$ = 2 788 053 600 Pa

$$\boldsymbol{v_k} = \frac{s*I_k}{\varphi*m_q}$$ = 687,912749 m/s

$$\boldsymbol{l_k} = l' * \left[(1 + b)^k - 1\right]$$ = 0,132947164

$$\boldsymbol{v_{ú}} = v_{lim} * \sqrt{1 - \left[1 - \left(\frac{v_k}{v_{lim}}\right)^2\right] * \left(\frac{l_1+l_k}{l_1+l_{ú}}\right)^{\theta}}$$ = 967,182021 m/s

3.2 Calculation no.2

m_q	0,0094	kg
α	0,0009229	m^3/kg
δ	1600	kg/m^3
χ	1,815	-
k_ϕ	1,1	-
c_0	0,000003521	m3
$l_ú$	0,448	m
I_k	170 000	Pa/s
K_c	1,2437	-
d	0,00762	m
s	0,0000437	m^2
f	1 009 500	J/kg
m_ω	0,0031	kg

$\Delta = \frac{m_\omega}{c_0}$ = 880,431696 kg/m^3

$l_0 = \frac{c_0}{s}$ = 0,080572 m

$\theta = \varkappa_c - 1$ = 0,2437

$\Lambda_ú = \frac{l_ú}{l_0} = \frac{l_ú * s}{c_0}$ = 0,0000195776

$\varphi = k_\varphi + \frac{1}{3} * k_{\chi str} * \frac{m_\omega}{m_q}$ = 1,16056751

$k_{\chi str} = \frac{1}{\Lambda_ú} * \left[\Lambda_ú + \left(\frac{1}{\chi} - 1\right) * ln(1 + \Lambda_ú)\right]$ = 0,550969

$v_{lim} = \sqrt{\frac{2 * f * m_\omega}{\theta * \varphi * m_q}}$ = 1 534,341777 m/s

$$\boldsymbol{a} = \boldsymbol{f} * \boldsymbol{m}_{\omega} = 3\,129{,}45 \text{ J}$$

$$\boldsymbol{j} = \boldsymbol{\varphi} * \boldsymbol{m_q} * \boldsymbol{v_k^2} = \boldsymbol{\varphi} * \boldsymbol{m_q} * \left(\frac{\boldsymbol{s} * \boldsymbol{I_k}}{\boldsymbol{\varphi} * \boldsymbol{m_q}}\right)^2 = 5\,058{,}97408 \text{ J}$$

$$\boldsymbol{b} = -\frac{\boldsymbol{\theta} * \boldsymbol{j}}{2 * \boldsymbol{a}} = -\frac{\boldsymbol{\theta} * \boldsymbol{s}^2 * \boldsymbol{I_k^2}}{2 * \boldsymbol{\varphi} * \boldsymbol{f} * \boldsymbol{m_q} * \boldsymbol{m_\omega}} \text{ -0,196979019}$$

$$\boldsymbol{k} = \frac{\boldsymbol{j}}{\boldsymbol{a} * \boldsymbol{b}} = -\frac{2}{\boldsymbol{\theta}} = \text{-8,20681165}$$

$$\boldsymbol{l}' = \frac{\boldsymbol{l}_\Delta + \boldsymbol{l_1}}{2} = 0{,}0256784246 \text{ m}$$

$$\boldsymbol{l}_\Delta = \boldsymbol{l_0} * \left(1 - \frac{\Delta}{\delta}\right) = 0{,}0362536609 \text{ m}$$

$$\boldsymbol{l_1} = \boldsymbol{l_0} * (1 - \boldsymbol{\alpha} * \Delta) = 0{,}0151031882 \text{ m}$$

$$\boldsymbol{A} = \frac{\boldsymbol{a}}{\boldsymbol{s} * \boldsymbol{l}'} = 2\,788\,053\ \ 600 \text{ Pa}$$

$$\boldsymbol{v_k} = \frac{\boldsymbol{s} * \boldsymbol{I_k}}{\boldsymbol{\varphi} * \boldsymbol{m_q}} = 680{,}976455 \text{ m/s}$$

$$\boldsymbol{l_k} = \boldsymbol{l}' * \left[(1 + \boldsymbol{b})^{\boldsymbol{k}} - 1\right] = 0{,}129723654 \text{ m}$$

$$\boldsymbol{v}_{\text{ú}} = \boldsymbol{v_{lim}} * \sqrt{1 - \left[1 - \left(\frac{\boldsymbol{v_k}}{\boldsymbol{v_{lim}}}\right)^2\right] * \left(\frac{\boldsymbol{l_1} + \boldsymbol{l_k}}{\boldsymbol{l_1} + \boldsymbol{l}_{\text{ú}}}\right)^{\boldsymbol{\theta}}} = 960{,}4329801 \text{ m/s}$$

4. PRACTICAL MEASURMENT OF MUZZLE VELOCITY.

The very last step of this work was to construct rounds with agreement with all parameters and their values. Due to the fact that every single change of each parameter can affect the weapon, we had to do it precisely. After construction we were ready to go shooting and measure values of muzzle velocity, so we could compare them and make the decision, if variance of bullet weight can affect the muzzle velocity in important way. In practical part that was about labouring bullets and shooting, we used different shots than in the theoretical part etc. We used shots about cal. 5,56mm. This ammo is typical for NATO states and is commonly used during fighting in built-up areas.

The valuesof weight were lower in comparison to shots from theoretical part, we had two samples, the 3,64g and 3,65g. Earlier I also calculated the innerballistics processes to evaluate the speed of muzzle, as you can see in a table below. Differences between calculated and measured muzzle velocities are known as human fault and also weather had its influence.

Weight of bullet	3,63g	3,65g
Calculated muzzle velocity	858,603 m/s	852,656m/s
Measured muzzle velocity	877,649m/s	871.994m/s

Table 3 Compared resuts

Picture 5: Samples after laboring

Picture 6: Devices for measuring muzzle velocity

CONCLUSION

In this work I tried to show how variance of bullet weight influences the muzzle velocity as one of the most important measured and calculated feature of military ballistics. There are many other features in calculating the muzzle velocity that definitely influence it, however this work is about showing the importance of difference of bullet weight. In heavy machine gun ammo, the difference is not so important due to fact, that this type of weapon is not used for accuracy shooting. However, assault rifles can easily be less effective due to influence of bullet weight variance because of usage of them as weapons used for accuracy shots. The muzzle weight is definitely changeable due to variance of bullet weight and the influence of this fact definitely affects external ballistics features that are essential for military ballistics. Despite the fact that this work shows mainly affects of bullet weight variance to muzzle velocity by numbers, reader can easily found ot that othr parameters are at least explicated. In this work I tried to show and I hope I also showed that the variance of bullet weight definitely affects the muzzle velocity in very important way.

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