Abstract: The article deals with improvement of accuracy of calculation of movement of the blowback breech during acceleration.

Key-Words: counting, movement, fire, weapon, blowback breech, unlocked breech, equation of motion

1 Introduction
Nowadays simulation and optimization of construction are common methods in technical practice because usually it is cheaper virtually test function of model system before its production. Although it is simple to count movement of blowback from energetical balance, results are only informative. In literature we can find dynamic analysis of blowback system [1] and also equation of motion for breech block is described. Despite of this, experience shows us that during maximum acceleration there is more than 15% disagreement between counting and measuring of breech velocity. We can reach satisfying results by the means breech mass coefficient or we have to create more sophisticated equation of motion.

2 Problem Formulation
The breech mass coefficient includes mainly influence of friction between cartridge case and barrel, friction between breech and weapon chasing and also effect of dynamic couple. But what value of the breech mass coefficient is suitable for typical construction? We can find variety of data from 1.1 [1] to 1.35 [2]. So it means maximum difference 25%. Due to of it the only way how to improve preciseness is new (modifying) equation of motion.

3 Problem Solution
Figure 1 schematically shows design of blow-back weapon system and main forces acting between parts. According to this picture initial equation of motion during acceleration of breech has a form

\[ \frac{d^2x}{dt^2} = F_{dn} - F_{pp} - F_{ex} - F_t \]  

where:
- \( F_{dn} \) - force to bottom in cartridge case (propelling force),
- \( F_{pp} \) - force of return spring (resistance force),
- \( F_{ex} \) - cartridge case extracting force (resistance force),
- \( F_t \) - frictional force between breech and breech casing (resistance force),
- \( m_z \) - total mass of moving parts.

\[ F_{ex} = \pi \cdot p_n \cdot d_{str} \cdot \mu (l_n - x) \]  

where:
- \( p_n \) - contact pressure between cartridge case and barrel,
- \( d_{str} \) - external diameter of the cartridge case’s shall,
- \( \mu \) - friction coefficient,
- \( l_n \) - length of cartridge case’s shall,
- \( x \) - breech travel.
Because it is not easy to determinate value $p_n$, sometimes pressure in cartridge case is taken into account ($p_n \approx p$). But more accurate pressure can be determined from equilibrium of force on cartridge case’s half axial cut (Fig. 2) in the y direction. If the Prandtl Reuss law of perfect plasticity is used, after rearrangement

$$p_n = \frac{p_{abs} \cdot (d_{str} - 2 \cdot \delta) - 2 \cdot R_{en} \cdot \delta}{d_{str}}$$  \hspace{1cm} (3)$$

where:

- $R_{en}$ - yield point material of cartridge case,
- $p_{abs}$ - mean value of pressure in the cartridge case.

Other coefficients are obvious from next picture.

Next interesting thing is pressure distribution in the space behind the projectile. This type of automatic operating systems is mostly used for pistol’s ammunition with short cartridge case. The low pressure gradient in cartridge case can be neglect and mean value of pressure in the cartridge case $p_{abs}$ is possible used (Fig. 4).

But we have to take into consideration pressure gradient between projectile and cartridge case’s bottom. According [4] the value of $p_{abs}$ could be counted from formula

$$p_{abs} = \frac{p}{1 + \frac{1}{3} \cdot k_x \cdot \omega \cdot \frac{\partial \cdot m_q}{\varphi_1 \cdot m_q} \cdot \{1 + \frac{1}{2} \cdot k_x \cdot \omega \cdot \frac{\varphi_1 \cdot m_q}{\varphi_1 \cdot m_q} \cdot [1 - \left(\frac{0.5 \cdot l_4}{(l_{kom} + l)}\right)^2]\}}$$ \hspace{1cm} (4)$$

where:

- $p$ - ballistic pressure,
- $k_x$ - coefficient of drop of propellant gases,
- $\varphi_1$ - constant (1.05 – 1.1 for hand arms),
- $\omega$ - mass of propellant,
- $m_q$ - mass of bullet,
- $l_{kom}$ - length of cartridge case’s chamber,
- $l$ - bullet trajectory.

On the basis of the cartridge case’s behavior during the fire forces acting on the cartridge case may be schematically drawn (Fig. 5).
but there are three forces which were not mentioned above:

\( F_k \) - the axis force of propellant gases to cone (slanted) parts of the cartridge case is for cylindrical cartridge case negligibly small.

\( F_{bm} \) - force from firing mechanism (resistance force) is due to low value and short time of functioning usually not considered.

\( F_v \) - extraction force of bullet from the cartridge case (resistance force) can be substituted by linear approximation (Fig. 6), and equation can be written as follow

\[
F_v = F_{v,max} \left[ 1 - \frac{1}{x_c} \cdot (x + l) \right]
\]  
(5)

where:

\( F_{v,max} \) - maximal extraction force of bullet from cartridge case,

\( x_c \) - length of forcing-in bullet in the cartridge case.

\[
F_v = F_{v,max} \left[ 1 - \frac{1}{x_c} \cdot (x + l) \right]
\]

friction coefficient \( \mu \) is dependent on moving of cartridge case according to relation \( \mu_s = 1,5 \mu_k \), where:

\( \mu_s \) - static friction coefficient,

\( \mu_k \) - dynamic friction coefficient,

zero distance between bullet and forcing cone – initial resistance against the motion of bullet through the forcing cone is included to starting value of pressure \( p_0 \).

The motion of the unlocked breech block (pure blow-back system) is possible to describe with these assumptions and above mentioned by the equation in shape

\[
m_c \cdot \frac{d^2 x}{dt^2} = -\pi \cdot p_d \cdot \frac{d_{bn}}{4} - \mu \cdot (l_n - e - x) \cdot (p_{abs} \cdot g - h)
\]  
(6)

\(-F_i - F_v - (F_i + c \cdot x)\),

where for the contraction these helpful expressions are used:

\[ e = 2,44 \cdot \sqrt{\frac{\delta \cdot (d_{bn} - \delta)}{2}} \],

\[ g = d_{bn} - 2 \cdot \delta \],

\[ h = 2 \cdot R_m \cdot \delta \],

\[
F_v = F_{v,max} \left[ 1 - \frac{1}{x_c} \cdot (x + l) \right]
\]

In the equation (6) means:

\( p_d \) - pressure to bottom in the cartridge case,

\( d_{bn} \) - diameter of bottom in the cartridge case,

\( d_{ns} \) - external diameter of the cartridge case’s shall, 

\( \mu \) - friction coefficient,

\( l_n \) - length of cartridge case’s shall,

\( \delta \) - mean thickness of cartridge case’s shall,

\( R_m \) - yield point material of cartridge case,

\( F_i \) - frictional force between breech and breech casing (depends on weapon design),

\( F_v \) - extraction force of bullet from cartridge case,

\( F_{v,max} \) - maximal extraction force of bullet from cartridge case,

\( x_c \) - length of forcing-in bullet in the cartridge case,

\( F_1 \) - preload of return spring,

\( c \) - stiffness of return spring,

\( m_z \) - mass of accelerating parts.

\[
m_z = m_b + m_n + \frac{1}{3} \cdot m_{pp}
\]  
(7)

where:

\( m_b \) - mass of breech,

\( m_n \) - mass of cartridge case,

\( m_{pp} \) - mass of return spring.

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1 The concrete constructional design of cartridge decides about character of this axis force (impulsive or resistance).
4 Conclusion
New (modifying) equation of motion of the blowback should be verified through technical experiment. Data from measurement have to be process by statistical analysis.

References: