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Effect of some parameters on the separation process of a saboted bullet

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Abstract:

Introduction/purpose: In this paper, the influence of muzzle velocity and the initial friction between the sabot and the penetrator of a sub-caliber bullet on the separation process was investigated. A special armor-piercing bullet was chosen as a research object.

Methods: A hybrid approach was applied in the study to solve the set tasks. In the first place, the equation system describing the motion of the sabot and the penetrator was established analytically. The aerodynamic drags acting on the sabot and the penetrator were then obtained numerically using CFD methods. Eventually, the equations of motion of the sabot and the penetrator were solved using the Runge-Kutta method to analyze the effect of the bullet muzzle velocity and the initial friction of the sabot and the penetrator on the separation process.

Results: The research results have shown the significant influence of the bullet muzzle velocity and the initial friction on the parameters of the sabot and the penetrator at the very moment they completely separate from each other. Based on the obtained data, weapon designers can appropriately select the ballistic and structural parameters for the bullet.

Conclusion: The hybrid approach presented in this paper is effective in studying the separation process of armor-piercing saboted bullets. The research results are useful contributions to the field of sub-caliber ammunition. The presented method can be applied in the design process of armor-piercing saboted projectiles of different calibers.

Key words: sabot separation, sub-caliber bullets, Ansys Fluent, CFD, numerical simulation.

Introduction

In the ongoing armed conflicts around the world today, soldiers are better protected on the battlefield. Ballistic vests are constantly improved to resist different types of bullets and projectiles. For instance, the Russian army has equipped its soldiers with RATNIK-3 smart suits (Dada et al, 2022). The Interceptor Body Armor (IBA) is widely used by soldiers in the US armed forces (Lestari et al, 2022). The increasing effectiveness of modern body armor poses an urgent need for weapon designers to find solutions to improve the penetration performance of bullets and projectiles. There are several solutions proposed to achieve this goal, such as increasing the muzzle kinetic energy of bullets, using bullets with cores made of heavy materials like tungsten carbide, depleted uranium, using discarding sabot, etc. Among them, the spin-stabilized sabot structure is a very promising direction. The most notable bullets which use this principle include Singaporean 12.7mm SLAP (Starek & Stepniak, 2021) and Swedish 6.5x25mm CBJ (CBJ Tech, 2024). Unlike standard bullets, this type of bullets has a number of different operating characteristics. The bullet is composed of a penetrator made of tungsten carbide or depleted uranium, a polymer sabot and an aluminum support. After exiting the barrel, under the effect of centrifugal force, the sabot deforms, its petals open to increase the area surface exposed to the air. The aerodynamic drag acting on the sabot is very large compared to the aerodynamic drag acting on the penetrator. As a result, the penetrator moves faster than the sabot and gradually separates from the sabot and continues to move towards the target alone as illustrated in Figure 1.

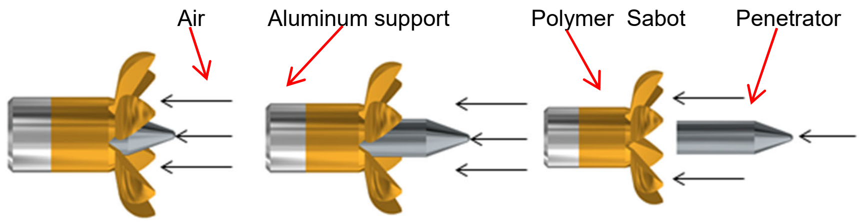


Figure 1 – Sabot separation process

Currently, although there is a large number of studies dedicated to the separation process of armour-piercing fin-stabilized discarding sabots (Lesage & Girard, 1996; Lin & Lai, 1997; Huang et al, 2014; Mohanan & Rajesh, 2020), there are very few studies on the sabot separation process of spin-stabilized sub-caliber projectiles. In a recent paper (Bui et al, 2024), the authors studied the separation process of a sub-caliber bullet with an aluminum sabot. Research results show that, for this structure, the difference between the aerodynamic drag acting on the sabot and the aerodynamic drag acting on the penetrator is not large; consequently, the range of the maximum allowable initial friction between the sabot and the penetrator is limited in a narrow interval. In this regard, the bullets with polymer sabots, like Swedish 6.5x25mm CBJ, have advantage over the bullets with aluminum sabots, as the aerodynamic drag acting on the deformed polymer sabot is much larger than the aerodynamic drag acting on the aluminum sabot. In our previous work (Nguyen et al, 2024), we investigated the supersonic flow around this kind of bullets. As a logical continuation of the recently mentioned studies, the main purpose of this paper is to investigate the influence of some parameters such as the initial friction between the sabot and the penetrator, as well as the influence of the bullet muzzle velocity on the separation process, namely, on the penetrator velocity at the separation moment and on the separation distance (distance from the gun muzzle to the position where the penetrator completely separates from the sabot) for this sub-caliber bullet. The method and research results presented in this study can be effectively adopted in the process of designing saboted bullets, particularly those with the structure like the structure of the Swedish 6.5x25mm CBJ bullet.

Materials and methods

Equations of motion for the sabot and the penetrator

The equations of motion for the sabot and the penetrator will be established based on the following assumptions: the gravity is negligible; the bullet moves with a zero angle of attack; the bullet rotational and translational motions are independent of each other; the opening angle of the sabot petals remain constant during the separation process. Consequently, the forces acting on the sabot and the penetrator are aerodynamic drags and friction.

The motion of the sabot and the penetrator is considered as the motion of two material points $\boldsymbol{O_s}$ and $\boldsymbol{O_p}$ respectively; here, $\boldsymbol{O_s}$ is the center of the cross section of the sabot bottom surface, and $\boldsymbol{O_p}$ is the center of the cross section of the penetrator aft surface, as shown in Figure 2.

The origin $\boldsymbol{O}$ of the coordinate system is the centre of the cross section of the penetrator aft surface at the very moment when the bullet exits the barrel. One can easily notice that, when the bullet leaves the gun muzzle, three points $\boldsymbol{O}$, $\boldsymbol{O_s}$ and $\boldsymbol{O_p}$ are at the same position. The positive direction of the coordinate axis is the same as of the bullet muzzle velocity vector as illustrated in Figure 3.

It is easy to derive the equations of motion for the sabot and the penetrator as follows (Bui et al, 2024):

$$\dot{v}_s = \frac{-F_{ds} + F_{fr}}{m_s}, \tag{1}$$

$$\dot{x}_s = v_s, \tag{2}$$

$$\dot{v}_p = \frac{-F_{dp} - F_{fr}}{m_p}, \tag{3}$$

$$\dot{x}_p = v_p, \tag{4}$$

Here, v_s is the sabot velocity; x_s is the sabot coordinate; m_s is the sabot mass; v_p is the penetrator velocity; x_p is the penetrator coordinate; m_p is the penetrator mass; F_{ds} is the aerodynamic drag acting on the sabot; F_{dp} is the aerodynamic drag acting on the penetrator; and F_{fr} is the friction force between the sabot and the penetrator.

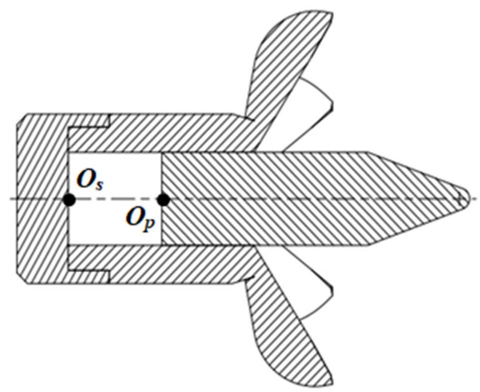


*Figure 2 – Material points **O_s** and **O_p***

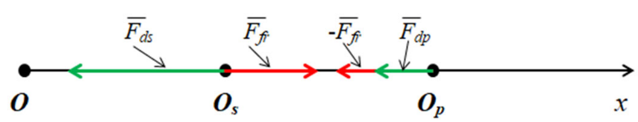


*Figure 3 – Forces acting on the sabot (**O_s**) and the penetrator (**O_p**)*

The initial conditions are as follows:

$$v_{s0} = v_{p0} = v_0;\ x_{s0} = x_{p0} = 0. \tag{5}$$

Here, v_{s0} is the sabot initial velocity; v_{p0} is the penetrator initial velocity; v_0 is the bullet muzzle velocity; x_{s0} is the sabot initial coordinate; and x_{p0} is the penetrator initial coordinate.

The friction force between the sabot and the penetrator can be determined as follows:

$$F_{fr} = f_{fr} pS\,. \tag{6}$$

Here f_{fr} is the friction coefficient between the sabot and the penetrator; p is the specific pressure acting on the contact surface between the sabot and the penetrator, and S is the contact surface area between the sabot and the penetrator. The parameter S can be determined through the following formula:

$$S = \pi d_p l\,, \tag{7}$$

where d_p is the penetrator diameter and l is the length of the longitudinal contact between the sabot and the penetrator as shown in Figure 4.

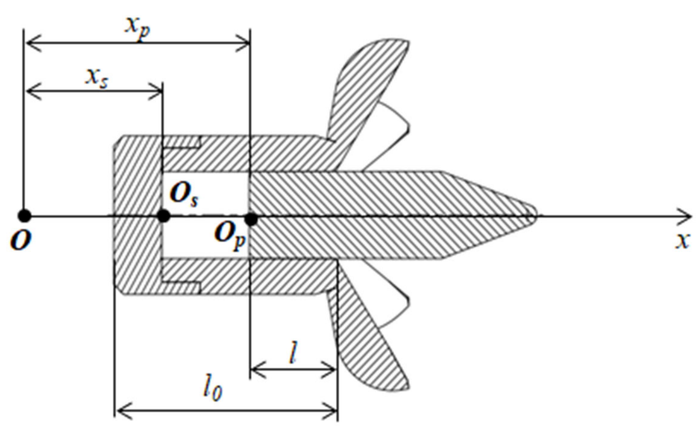


Figure 4 – Length of the longitudinal contact between the sabot and the penetrator

The parameter l can be defined through the following expression:

$$l = l_0 - (x_p - x_s)\,, \tag{8}$$

where l_0 is the initial length of longitudinal contact between the penetrator and the sabot. The penetrator is considered completely separated from the sabot when there is no mechanical contact between them, which means l = 0.

Substituting (7) into (6) gives:

$$F_{fr} = f_{fr} p \pi d_p l = f_{fr} p \pi d_p l_0 \times \frac{l}{l_0}. \quad (9)$$

Naming $F_{fr0} = f_{fr} p \pi d_p l_0$, it is obvious that F_{fr0} is the initial friction between the sabot and the penetrator when the bullet just exits the muzzle. As a result, formula (6) can be rewritten in the following way:

$$F_{fr} = f_{fr} p \pi d_p l = F_{fr0} \times \frac{l}{l_0}. \quad (10)$$

It is easy to notice that the friction between the sabot and the penetrator at that moment linearly depends on their initial friction.

Solution method

The system of equations (1), (2), (3), (4), (8), (10) in conjunction with the initial condition (5) can be integrated if the aerodynamic drags F_{ds} and F_{dp} are known at any time step. The following method is proposed to determine these drags. First step - the aerodynamic drags will be obtained numerically at certain discrete points using CFD methods. Next, F_{ds} and F_{dp} will be approximated using the numerical method. With the sabot and the penetrator of fixed dimensions, the aerodynamic drags acting on the sabot and the penetrator are only dependent on their velocities and relative positions, which means they can be presented as follows:

$$F_{ds} = F_{ds}(v_s, l),\ F_{dp} = F_{dp}(v_p, l). \quad (11)$$

Hence, using the CFD method, for instance, performing simulation on the Ansys Fluent software package, one can obtain F_{ds} and F_{dp} at certain discrete points. Then the bilinear interpolation method can be applied to approximate the value of aerodynamic drags at any given point of velocity and relative position (*v, l*). Finally, the equation system will be solved using, for instance, the fourth order Runge-Kutta method.

Determination of the aerodynamic drags

In order to obtain the aerodynamic drags acting on the sabot and the penetrator, Ansys Fluent software was utilized in this research. The simulation procedure has been introduced in numerous works (Jerković et al, 2016; Matsson, 2023; Ferfouri et al, 2023). The 3D models of the bullet were created in Inventor CAD software. For the purpose of simplification, the aluminum support and the polymer sabot were modeled as a unified object as shown in Figure 5. It is acceptable as they are connected together for the entire separation process. A simulation air domain was initiated with the size of 40L x 10L x 10L as presented in Figure 6; here *L* is the bullet length. A grid sensitivity study has indicated that, in our case, for a 3D RANS simulation, the grid of about 4.45 million elements could provide sufficiently accurate results. The mesh around the bullet is presented in Figure 7. In our case, the aerodynamic drags acting on both the sabot and the penetrator are needed, so the exposed to the air surfaces of the penetrator and the sabot are named individually as shown in Figure 8. The turbulence model k-ε was used. The density-based solver was applied. The air was considered the ideal gas. The air viscosity model was the Sutherland model. Velocity, static pressure, and static temperature were set for the inlet flow. Static pressure was defined for the outlet flow. The Coupled algorithm was utilized in this study to ensure the simulation accuracy. The convergence criterion was set to 10-5.

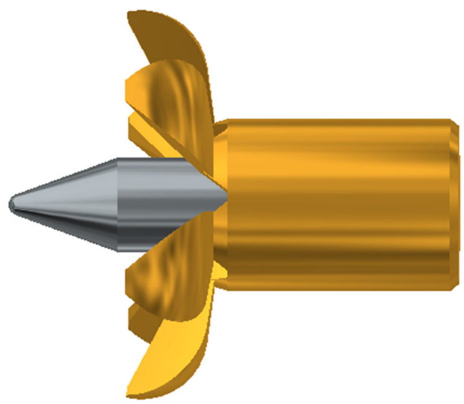


Figure 5 – 3D model of the bullet

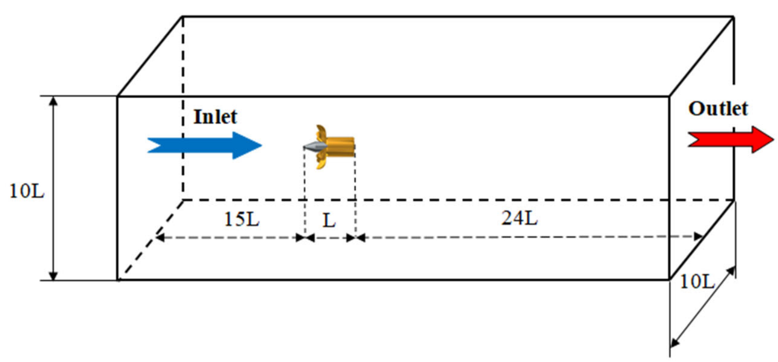


Figure 6 – Simulation air domain

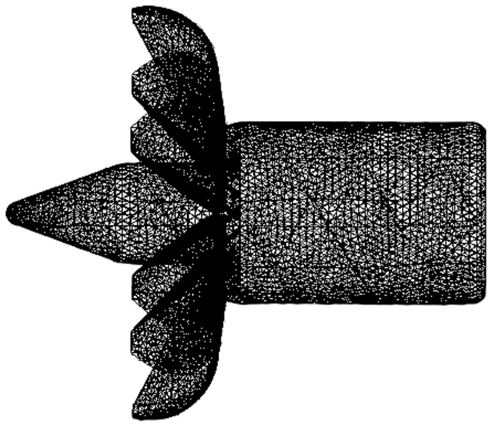
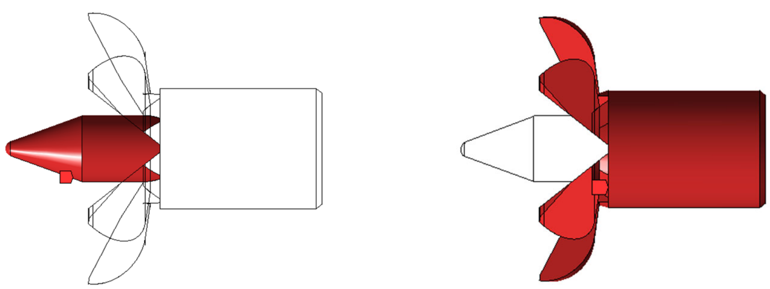


Figure 7 – Mesh around the bullet



a) Named section for the penetrator *b) Named section for the sabot*

Figure 8 – Named sections for the penetrator (a) and the sabot (b)

Approximation of the aerodynamic drags

After the determination of the aerodynamic drags acting on the penetrator and the sabot at certain discrete points of velocity and their relative positions, the next step is to approximate them at any given time step based on their current velocity and relative position. To achieve this goal, the bilinear interpolation method was implemented. Assume that, using Ansys Fluent, the aerodynamic drag *F* has been determined at four given points $F_{11}(v_1, l_1)$, $F_{12}(v_1, l_2)$, $F_{21}(v_2, l_1)$, $F_{22}(v_2, l_2)$. According to the bilinear interpolation method (Kang, 2006), the value of drag $F(v, l)$, where $v_1 < v < v_2$ and $l_1 < l < l_2$, could be approximated as follows:

$$F(v,l) = F_{11} + (F_{21} - F_{11})\frac{v - v_1}{v_2 - v_1} + (F_{12} - F_{11})\frac{l - l_1}{l_2 - l_1} + (F_{22} - F_{12} - F_{21} + F_{11})\frac{(v - v_1)(l - l_1)}{(v_2 - v_1)(l_2 - l_1)}.$$

In general, after the approximation of the aerodynamic drags acting on the penetrator and the sabot, the equations of motion of the penetrator and the sabot can be integrated to analyze the separation process.

Results and discussion

Although sub-caliber bullets have some significant advantages over standard bullets in terms of impact velocity and ballistic performance, they require a proper separation process to ensure that the penetrator will function correctly during the next flight stage to the target. The sabot separation process of sub-caliber bullets is affected by multiple factors such as the bullet velocity, aerodynamics, the bullet structure and materials, etc. In this study, the influence of the bullet muzzle velocity and the initial friction between the sabot and the penetrator on the separation process, specifically, on the penetrator velocity at the separation moment and on the separation distance (the distance from the gun muzzle to the point where the penetrator loses mechanical contact with the sabot) will be investigated. The configuration of the penetrator, the aluminum support and the polymer sabot are presented in Figure 9, Figure 10 and Figure 11, respectively.

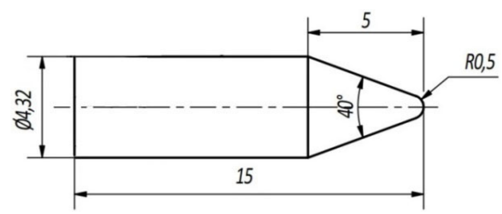


Figure 9 – Penetrator configuration (in mm)

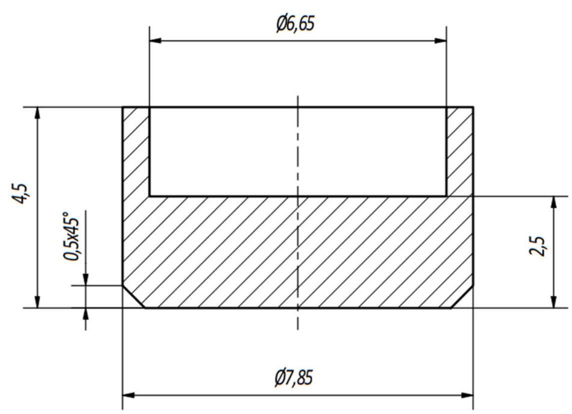


Figure 10 – Aluminum support configuration (in mm)

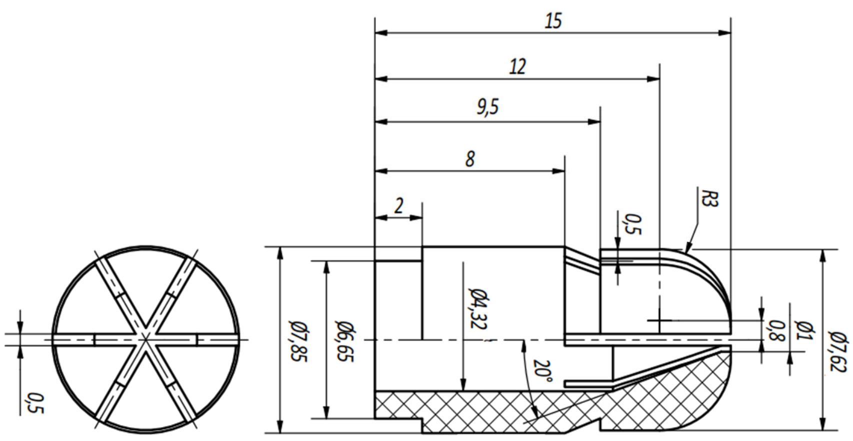


Figure 11 – Polymer sabot configuration (in mm)

In addition, the main parameters of the sabot and the penetrator are presented in Table 1.

Table 1 – Main parameters of the bullet

Parameter	Units	Notation	Value
Mass of the support and the sabot	*kg*	m_s	0.00079
Mass of the tungsten penetrator	*kg*	m_p	0.00274
Initial length of the longitudinal contact	*m*	*l*	0.008

Estimation of the maximum allowable initial friction

The bullet consists of three components: aluminum support, polymer sabot and tungsten carbide penetrator. To ensure the integrity of the bullet, there must be sufficient friction between the sabot and the penetrator. However, if the friction is too large, it can negatively affect the separation process. For instance, the penetrator may take too long to completely separate from the sabot, or in the worst-case scenario, the penetrator could not leave the sabot at all. Hence, an appropriate initial friction between the penetrator and the sabot must be selected to ensure a proper sabot separation.

For the penetrator to leave the sabot reliably, it has to maintain a velocity greater than the sabot velocity during the separation process, which means:

$$v_p > v_s . \tag{12}$$

Combining with (1) and (3), one obtains:

$$\int_0^t \frac{-F_{dp} - F_{fr}}{m_p} dt + v_{p0} > \int_0^t \frac{-F_{ds} + F_{fr}}{m_s} dt + v_{s0} \tag{13}$$

Since $v_{p0} = v_{s0}$, expression (13) becoms:

$$\int_0^t \frac{-F_{dp} - F_{fr}}{m_p} dt > \int_0^t \frac{-F_{ds} + F_{fr}}{m_s} dt \tag{14}$$

During the first small period of time immediately after the bullet exits the gun muzzle, the friction between the sabot and the penetrator as well as the aerodynamic drags acting on the sabot and the penetrator change very little and can be considered constant. Then (14) becomes:

$$\frac{-F_{dp0} - F_{fr0}}{m_p} > \frac{-F_{ds0} + F_{fr0}}{m_s} \tag{15}$$

where F_{dp0}, F_{ds0}, respectively, are the initial aerodynamic drags acting on the penetrator and the sabot when the bullet just leaves the gun barrel. After performing some simple algebraic transformations to (15), one obtained the following relationship:

$$F_{fr0} < \frac{m_p F_{ds0} - m_s F_{dp0}}{m_p + m_s} \tag{16}$$

Formula (16) is the necessary condition for the initial friction between the sabot and the penetrator to ensure that the penetrator can separate from the sabot. It is easy to see that the maximum allowable friction is greater if the mass of the penetrator and the initial aerodynamic drag acting on the sabot are greater, and vice versa, when the mass of the sabot and the aerodynamic drag acting on the penetrator are smaller. Relationship (16) helps designers determine the maximum allowable initial friction between the sabot and the penetrator to ensure that the sabot separation process can occur.

Based on formula (16), the maximum allowable initial friction between the sabot and the penetrator was determined for the bullet muzzle velocity ranging from 600 m/s to 700 m/s with the increments of 20 m/s. The effect of the bullet muzzle velocity on the maximum allowable initial friction is shown in Figure 12.

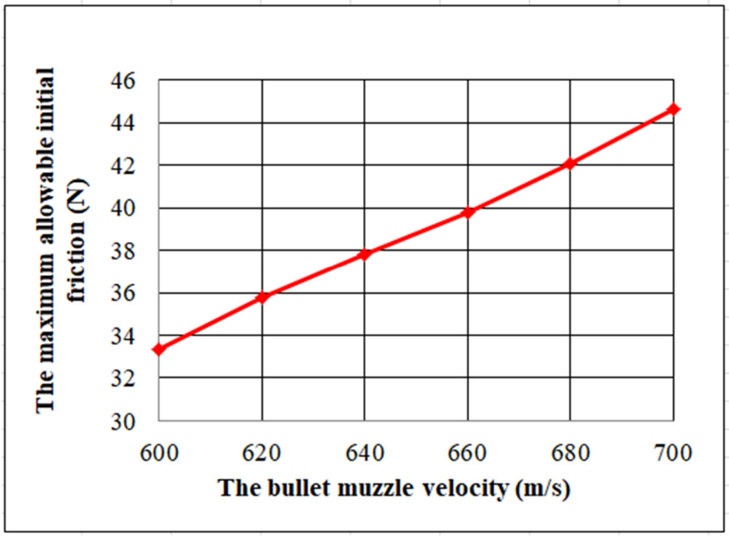


Figure 12 – Effect of the bullet muzzle velocity on the maximum allowable initial friction between the sabot and the penetrator

Clearly, the greater bullet muzzle velocity, the greater maximum allowable initial friction. The dependence of the maximum allowable initial friction on the bullet muzzle velocity is almost linear.The maximum allowable initial friction increases from 33.3 N to 44.6 N when the bullet muzzle velocity changes from 600 m/s to 700 m/s.

Influence of the initial friction

As mentioned before, the initial friction between the sabot and the penetrator is an important parameter, effecting not only the functinality but also the separation process of sub-caliber bullets. Based on the presented hybrid approach, the influence of the initial friction on the separation process was carried out for the bullet muzzle velocity of 640 m/s, 660 m/s, 680 m/s and 700 m/s. The initial friction varied from 5 N to 37 N with the increments of 5 N. The effect of the initial friction on the separation distance is presented in Figure 13.

Obviousy, the greater the initial friction, the greater the separation distance. Moreover, the dependence of the separation distance on the initial friction has a similar trend for all values of the bullet muzzle velocity. The separation distance increases quickly when the initial friction increases, especially for lower bullet muzzle velocity. At small initial friction, the separation distance is almost the same for every muzzle velocity, but at greater initial friction, the separation distance greatly differs with different muzzle velocities.

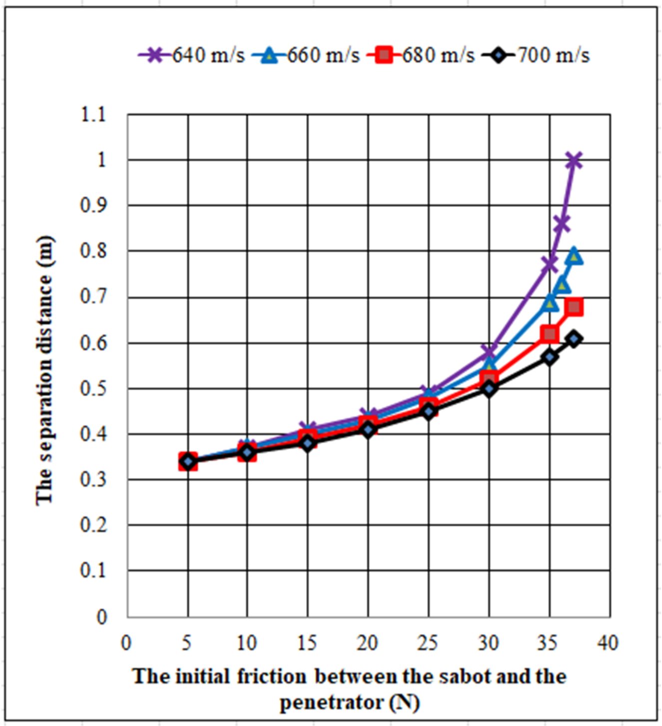


Figure 13 – Effect of the initial friction between the sabot and the penetrator on the separation distance

The dependence of the penetrator velocity at the separation moment on the initial friction is shown in Figure 14. Clearly, if the initial friction increases, the penetrator velocity at the separation moment decreases due to aerodynamic loss. For a given muzzle velocity, the greater initial friction, the higher penetrator velocity loss at the separation moment.

The influence of the initial friction on the penetrator velocity at the separation moment is practically identical for different muzzle velocities.

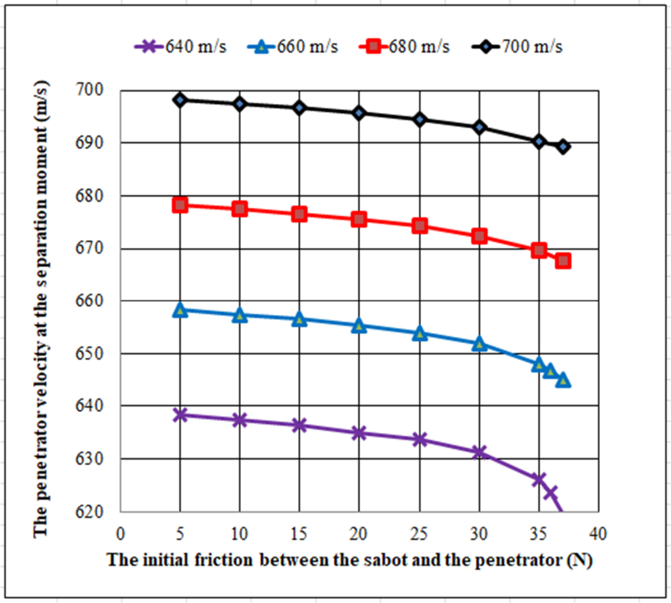


Figure 14 – Effect of the initial friction on the penetrator velocity at the separation moment

Influence of the bullet muzzle velocity

The bullet muzzle velocity plays a crucial role in ammunition design practice. It affects the trajectory, flight stability and ballistic performance of the bullet. A consistent muzzle velocity leads to more predictable flight paths, which is very important for accuracy, especially over longer distances. Changes in the bullet muzzle velocity can result in differing points of impact, affecting precision. Higher muzzle velocities generally lead to greater kinetic energy and better penetration. Higher muzzle velocities also help keep the bullet's stability and speed over longer distances, lowering the effects of gravity and wind drift. However, besides these advantages, higher muzzle velocities also could result in several negative effects. First of all, high velocities can accelerate wear on the gun barrel, due to increased heat and pressure. This can reduce the longevity of the weapon and potentially lead to more frequent maintenance or even structural damage over time. Higher muzzle velocities generally lead to increased recoil. This recoil can be uncomfortable for soilders, affecting their ability to maintain accuracy and control during firing. Consequently, it is necessary to select appropriate muzzle velocities to solve a concrete given task.

In this paper, the equations of motion of the sabot and the penetrator were solved for the bullet muzzle velocity of 640 m/s, 660 m/s, 680 m/s and 700 m/s at various values of initial friction ranging from 20 N to 37 N with icrements of 5 N. The influence of the bullet muzzle velocity on the separation distance and the penetrator velocity at the separation moment is presented in Figure 15 and Figure 16.

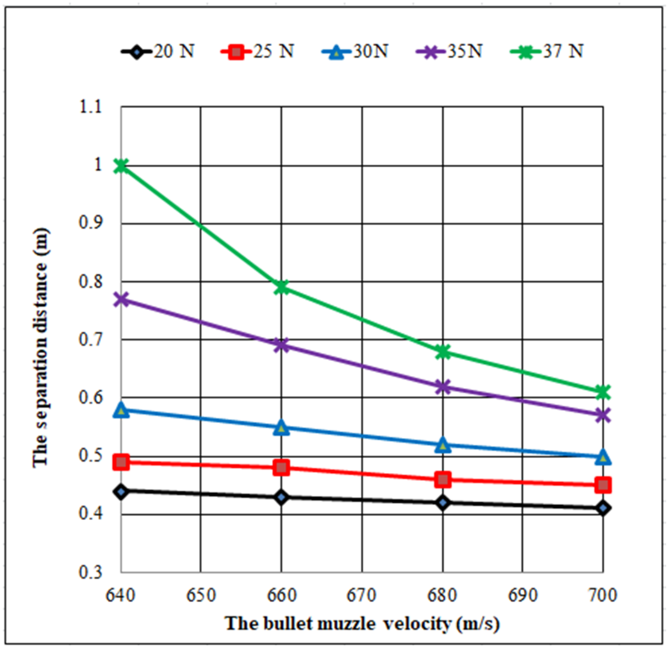


Figure 15 – Effect of the bullet muzzle velocity on the separation distance

It is apparent that the separation distance decreases with the increase of muzzle velocity. Moreover, a clear trend can be observed that, the greater initial friction, the more significant influence the muzzle velocity has on the separation distance. At the initial friction of 20 N, the separation distance only changes slightly when the muzzle velocity increases from 640 m/s to 700 ms. But at the initial friction of 37 N, the separation distance changes significantly with the change of muzzle velocity.

The effect of the muzzle velocity on the penetrator velocity at the separation moment has nearly identical and linear characteristics for different values of initial friction.

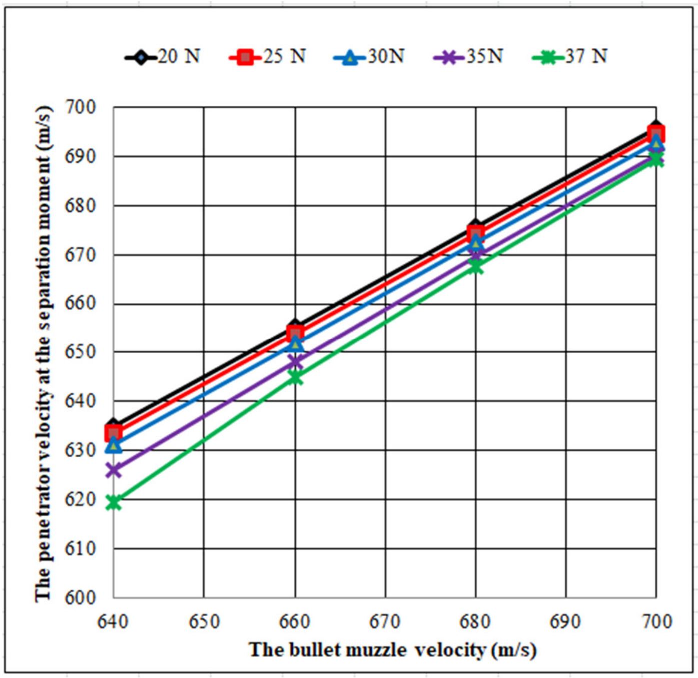


Figure 16 – Effect of the muzzle velocity on the penetrator velocity at the separation moment

Conclusion

In this study, the effect of the muzzle velocity and the initial friction between the sabot and the penetrator of a special armor-piercing sub-caliber bullet on its separation process was investigated using a hybrid approach of analytical and numerical methods. The following conclusions can be deduced from the research:

The bullet muzzle velocity significantly affects the separation process. Namely, the greater muzzle velocity, the higher maximum allowable initial friction between the sabot and the penetrator. Additionally, when the muzzle velocity increases, the separation distance decreases significantly.

The initial friction between the sabot and the penetrator has a significant impact on the separation process. Specifically, when the initial friction increases, the separation distance also quickly increases and the penetrator velocity at the separation moment drops notably. This trending influence especially becomes more apparent as the initial friction gradually approaches its maximum allowable value.

The results obtained in this work can be used for selecting suitable values of muzzle velocity and initial friction between the sabot and the penetrator in the process of designing sub-caliber bullets of the studied or similar structures.

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El efecto de algunos parámetros en el proceso de separación de una bala sabot

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CAMPO: ingeniería mecánica, dinámica de fluidos, balística exterior.
TIPO DE ARTÍCULO: artículo científico original

Resumen:

Introducción/objetivo: En este artículo, se investigó la influencia de la velocidad de salida y la fricción inicial entre el sabot y el penetrador de una bala de sub-calibre en el proceso de separación. Como objeto de investigación se eligió una bala especial perforadora de armaduras.

Métodos: En el estudio se aplicó un enfoque híbrido para resolver las tareas planteadas. En primer lugar, se estableció analíticamente el sistema de ecuaciones que describe el movimiento del sabot y del penetrador. Las resistencias aerodinámicas que actúan sobre el sabot y el penetrador se obtuvieron numéricamente utilizando métodos CFD. Finalmente, las ecuaciones de movimiento del sabot y del penetrador se resolvieron utilizando el método de Runge-Kutta para analizar el efecto de la velocidad de salida de la bala y la fricción inicialdel sabot y el penetrador en el proceso de separación.

Resultados: Los resultados de la investigación han demostrado la influencia significativa de la velocidad de salida de la bala y la fricción inicial sobre los parámetros del sabot y del penetrador en el momento en que se separan completamente uno del otro. A partir de los datos obtenidos, los diseñadores de armas pueden seleccionar adecuadamente los parámetros balísticos y estructurales de la bala.

Conclusión: El enfoque híbrido presentado en este artículo es eficaz para estudiar el proceso de separación de balas sabot perforantes. Los resultados de la investigación son contribuciones significativas al campo de las municiones de subcalibre. El método presentado se puede aplicar en el proceso de diseño de proyectiles sabot perforantes de diferentes calibres.

Palabras claves: separación de sabot, balas de subcalibre, Ansys Fluent, CFD, simulación numérica.

Влияние некоторых параметров на процесс отделения сердечника от поддона подкалиберной пули

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РУБРИКА ГРНТИ: 30.17.33 Газовая динамика,
30.17.53 Прикладная аэродинамика
ВИД СТАТЬИ: оригинальная научная статья

Резюме:

Введение/цель: В данной работе исследовано влияние начальной скорости и начального трения между поддоном и сердечником подкалиберной пули на процесс их отделения. Предметом исследования была специальная бронебойная пуля.

Методы: Для решения поставленных задач был применен гибридный подход. Прежде всего аналитически была установлена система уравнений, описывающая движение поддона и сердечника. Аэродинамическое сопротивление, действующие на поддон и сердечник было получены численно с использованием методов CFD. В конечном итоге уравнения движения поддона и сердечника были решены с использованием метода Рунге-Кутты для анализа влияния начальной скорости пули и начального трения на процесс отделения.

Результаты: Результаты исследований показали существенное влияние начальной скорости пули и начального трения на параметры поддона и сердечника в момент их полного отделения друг от друга. На основе полученных данных *конструкторы оружия могут соответствующим образом подобрать баллистические и конструктивные параметры пули.*

Выводы: Представленный в статье гибридный подход эффективен в изучении процесса отделения сердечника от поддона подкалиберной пули. Результаты исследований являются полезным вкладом в область подкалиберных боеприпасов. Представленный метод может быть применен в процессе проектирования бронебойных подкалиберных снарядов различного калибра.

Ключевые слова: отделение подкалибра, подкалиберные пули, Ansys Fluent, CFD, численное моделирование.

Утицај неких параметара на процес одвајања поткалибарног пројектила са одвојивим носачем (саботом)

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ОБЛАСТ: машинство, динамика флуида, спољашња балистика
КАТЕГОРИЈА (ТИП) ЧЛАНКА: оригинални научни рад

Сажетак:

Увод/циљ: У овом раду истражен је утицај брзине пројектила на устима цеви и почетног трења између носача (сабота) и пенетратора поткалибарног пројектила на процес раздвајања. За објекат истраживања изабран је специјални панцирни пројектил.

Методе: За решавање постављених задатака у студији је примењен хибридни приступ. На почетку, аналитички је успостављен систем једначина који описује кретање сабота и пенетратора. Затим је аеродинамички отпор који делује на носач (сабот) и пенетратор добијен нумеричким путем коришћењем CFD методе. На крају су једначине кретања сабота и пенетратора решене применом методе Рунге-Кута да би се анализирао ефекат брзине пројектила на устима цеви и почетног трења сабота и пенетратора на процес раздвајања.

Резултати: Резултати истраживања су показали значајан утицај брзине на устима цеви и почетног трења на параметре сабота и пенетратора у тренутку потпуног одвајања. На основу добијених података, пројектанти оружја могу да одаберу, на одговарајући начин, балистичке и структурне параметре за пројектил.

Закључак: Представљен хибридни приступ ефикасан је у проучавању процеса одвајања панцирних поткалибарних *пројектила са одвојивим носачем. Резултати истраживања представљају значајан допринос у области поткалибарне муниције. Приказани метод може се применити у процесу пројектовања панцирних поткалибарних пројектила са одвојивим носачем различитих калибара.*

Кључне речи: одвајање носача (сабота), поткалибарни пројектили, Ansys Fluent, CFD, нумеричка симулација.

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