RESEARCH AND DESIGN OF MULTI-PROJECTILE AMMUNITION FOR SHORT-RANGE ANTI-UAV INFANTRY WEAPONS

NGHIÊN CỨU THIẾT KẾ ĐẠN NHIỀU ĐẦU CHỐNG UAV TẦM GẦN DÙNG CHO SÚNG BỘ BINH

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ABSTRACT

This paper investigates a 7.62 mm multi-submunition (multi-lethal element) projectile model designed to enhance combat effectiveness against low-altitude, small-scale, and highly maneuverable targets, specifically Unmanned Aerial Vehicles (UAVs). The proposed configuration features three submunitions capable of aerodynamic separation upon exiting the muzzle, creating a wide-area impact distribution rather than the single-point impact characteristic of conventional ammunition. The study employs Computational Fluid Dynamics (CFD) simulations to determine the aerodynamic characteristics and the drag coefficient (C_x) of each component. Based on these findings, the impact point distribution was calculated and validated through experimental firing tests. The results demonstrate that, with a muzzle velocity of 550 m/s, the multi-submunition design achieves an impact count three times higher than that of traditional single-projectile ammunition. The impact distribution radii at ranges of 75 m and 100 m reached 37 cm and 75 cm, respectively, confirming the optimized capability for neutralizing small-scale UAVs and enemy personnel at short ranges.

Keywords: *Multi-submunition projectile; UAV; Aerodynamic simulation; External ballistics.*

TÓM TẮT

Bài báo nghiên cứu mô hình đạn súng nhiều đầu (nhiều phần tử sát thương) cỡ 7,62 mm nhằm nâng cao hiệu quả tác chiến đối với các mục tiêu bay thấp, cỡ nhỏ và cơ động như phương tiện bay không người lái (UAV). Cấu hình đề xuất bao gồm ba đầu đạn con có khả năng phân tách khí động học sau khi rời miệng nòng, tạo ra vùng bao phủ điểm chạm diện rộng thay vì một điểm đơn lẻ như đạn truyền thống. Nghiên cứu sử dụng phương pháp mô phỏng số động lực học chất lưu (CFD) để xác định các đặc trưng khí động và hệ số lực cản chính diện (C_x) của từng thành phần. Trên cơ sở đó, tính toán và kiểm chứng thông qua thực nghiệm bắn thử để đánh giá phân bố vùng điểm chạm. Kết quả cho thấy, với sơ tốc đầu nòng 550 m/s, thiết kế đạn nhiều đầu cho phép tạo ra số lượng điểm chạm cao gấp 3 lần so với đạn đơn truyền thống. Vùng phân bố điểm chạm tại cự ly 75 m và 100 m lần lượt đạt bán kính 37 cm và 75 cm, khẳng định khả năng tối ưu hóa trong việc tiêu diệt mục tiêu UAV cỡ nhỏ và sinh lực địch ở tầm gần.

Từ khóa: *Đạn nhiều đầu; UAV; Mô phỏng khí động; Thuật phóng ngoài.*

1. INTRODUCTION

The rapid proliferation of small-scale Unmanned Aerial Vehicles (UAVs) has posed significant challenges to short-range defense systems. Due to their compact dimensions, high maneuverability, and low-altitude flight profiles, UAVs substantially diminish the effectiveness of conventional infantry ammunition, which suffers from low hit probability and requires extreme precision within very short engagement windows.

Globally, extensive research has focused on enhancing the kill probability against small, low-flying targets, with a prominent trend being the development of multi-lethal element munitions [1], [2], [4]. Notably, in 2026, Russia announced a new type of multi-bullet anti-UAV ammunition, such as the "Mnogotochie", capable of separating into multiple elements after being fired from standard rifles. This design reportedly increases the neutralization efficiency against small targets by approximately 2.5 times within a range of up to 300 m [3]. Other variants have also been prototyped with configurations consisting of three or more submunitions to create a broader coverage area against fast-moving and maneuverable UAVs [2]. However, both internationally and in Vietnam, official publications and comprehensive research on this specific ammunition type remain limited, with most efforts still in the prototyping stage. These developments underscore a clear shift from single-projectile rounds to multi-element configurations to counter UAV threats in modern warfare [1], [5].

Driven by these requirements, this paper focuses on the research and design of a multi-submunition anti-UAV projectile for short-range applications in infantry weapons. The study integrates aerodynamic simulation and external ballistics analysis, complemented by the prototyping and experimental testing of 7.62×39 mm ammunition to evaluate its effectiveness and practical feasibility.

2. PROBLEM MODELING

The paper investigates a multi projectile model consisting of three elements (three submunitions) with a stacked cylinder-cone configuration (Figure 1) in 7.62 mm caliber. The submunitions feature a pointed conical shape to ensure aerodynamic stability and maintain the primary flight trajectory. Meanwhile, the lengths of the conical and cylindrical sections vary among the submunitions to facilitate separation upon exiting the muzzle, driven by aerodynamic forces and inertial moments during the transition phase. The projectile is designed to be compatible with standard-issue infantry rifles, including the AK, STV380, and STV215.

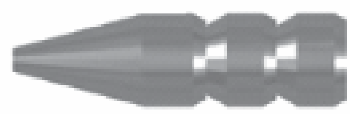


Figure 1. Multi projectile Model

The motion of the projectile upon exiting the muzzle can be divided into two distinct phases: the pre-separation phase and the independent flight phase following separation (with the separation process itself being neglected).

During the initial phase ($0 \le t \le t_t$), as the submunitions are aligned along the same flow axis, the aerodynamic forces acting on each element differ significantly. This is primarily due to the influence of the aerodynamic wake (shielding effect) behind the leading submunition. Consequently, the drag coefficients of the submunitions are not identical ☞

and are determined through Computational Fluid Dynamics (CFD) numerical simulations.

Aerodynamic forces acting on individual submunitions:

$$F_{di} = \frac{1}{2}\rho C_{xi} A_i v^2$$

Where: ρ is the air density; C_{xi} is the drag coefficient, determined through Computational Fluid Dynamics (CFD) numerical simulations; A_i, v_i are the cross-sectional area and the velocity of each submunition, respectively.

Due to the variations in C_{xi}, separation force is generated between the submunitions:

$$F_{12} = F_{d1} - F_{d2}; \quad F_{23} = F_{d2} - F_{d3}$$

Separation occurs when this acting force exceeds the bonding strength:

$$F_{12} \geq F_{lk12};\ F_{23} \geq F_{lk23}$$

Substituting into the drag force expression:

$$\frac{1}{2}\rho v^2 (C_{x1}A_1 - C_{x2}A_2) \geq F_{lk12};\ \frac{1}{2}\rho v^2 (C_{x2}A_2 - C_{x3}A_3) \geq F_{lk23}$$

Flight stage of the submunitions after separation ($t > t_t$). After the time t_t, the submunitions are assumed to separate instantaneously and move independently. Each submunition has a mass m_i, a drag area A_i, and a drag coefficient C_{xi}.

$$m_i \frac{d\vec{v_i}}{dt} = -\frac{1}{2}\rho C_{xi} A_i v_i^2 \vec{v_i} + m_i.\vec{g}$$

$$\frac{dv_{xi}}{dt} = -k_i v_i v_{xi}, \quad \frac{dv_{yi}}{dt} = -k_i v_i v_{yi}, \quad \frac{dv_{zi}}{dt} = -g - k_i v_i v_{zi}.$$

Với $k_i = \dfrac{\rho C_{xi} A_i}{2m_i}$

The two-stage model, based on the assumption of instantaneous separation, simplifies the problem while preserving the primary characteristics of the motion, particularly the influence of muzzle velocity, separation timing, and the aerodynamic properties of each sub-projectile on the spatial distribution of the impact points.

3. SOLUTION METHODOLOGY

The system of motion equations for the two stages is solved using numerical methods. First, the equations of motion of the projectile system in the pre-separation stage are integrated over time using the Runge–Kutta method to determine the evolution of velocity v(t) and the trajectory x(t).

After determining the state at the separation instant, the equations of motion for each sub-projectile are solved independently with the corresponding initial conditions. The flight trajectory of each element is then obtained, and the impact point is determined at the instant when the sub-projectile reaches the target plane. The collection of these impact points is used to construct the spatial distribution and to evaluate the effectiveness of the coverage expansion provided by the multi-projectile round.

The drag coefficients C_{xi} of the individual sub-projectiles are determined through Computational Fluid Dynamics (CFD) simulations and serve as input parameters for the numerical model.

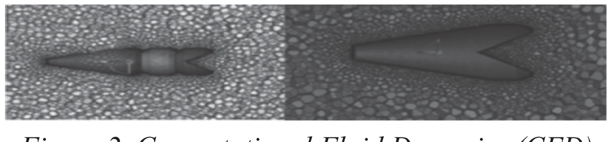


Figure 2. Computational Fluid Dynamics (CFD) simulation model.

Table 1. Aerodynamic flow input parameters.

Parameters	Value	Parameters	Value
Cross-sectional area	4.56×10^5 m²	Ambient air pressure	101325 Pa
Air density	1.176653 kg/m³	Temperature	300 K
Airflow velocity	300...600 m/s	Reference air viscosity	1.789×10^{-5}
Projectile diameter	7.62 mm		

In addition to the theoretical calculations, multi-submunition prototypes were fabricated based on the selected design parameters to validate the computational model. Firing tests were conducted against targets at specified ranges to determine the impact points of each submunition. The experimental results were then compared with the calculated data to evaluate the accuracy and consistency of the proposed model.

4. RESULTS AND DISCUSSION

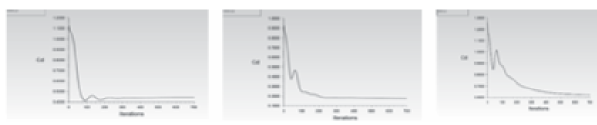
4.1. CFD simulation results for determining drag coefficients across different stages

Numerical simulations were performed using ANSYS Fluent to analyze the flow field around the submunitions across various velocity ranges. The simulation results for the pre-separation stage are presented as follows (Figure 3):

a) Pressure contours b) Velocity contours

Figure 3. Aerodynamic simulation results for the submunitions in the pre-separation stage

The CFD results for the velocity and static pressure fields of the three-element projectile configuration in the pre-separation stage demonstrate pronounced aerodynamic interactions among the elements. The leading sub-projectile generates a strong compression region followed by an extended wake, which reduces the flow velocity and dynamic pressure experienced by the downstream elements. As a result, the trailing sub-projectiles operate within a disturbed flow field rather than under free-stream conditions. Additional effects, including local flow compression within the inter-element gaps and a low-pressure region at the base of the third sub-projectile, further modify the aerodynamic loads. These phenomena lead to a non-uniform axial pressure distribution and significant differences in drag coefficients among the sub-projectiles. The resulting drag disparity induces an axial tensile force, which governs the separation mechanism and provides the basis for determining stage-dependent aerodynamic parameters in the exterior ballistics model (Figure 4, 5).



a) C_{x1} b) C_{x2} c) C_{x3}

Figure 4. Drag coefficient results of the sub-projectiles in the pre-separation stage (CFD simulation).

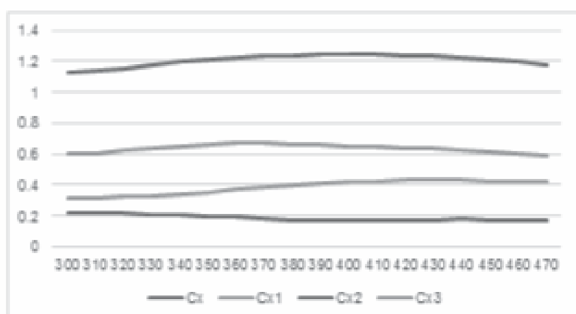


Figure 5. CFD-based variation of drag coefficient C ☞

From the CFD simulation results, it is observed that the drag coefficient C_x of each submunition fluctuates significantly as the velocity varies. Specifically, the C_x values increase slightly in the subsonic region before decreasing. Consequently, average C_x values are employed in the computational process. The simulation results indicate that $C_{x3} > C_{x1} > C_{x2}$, which implies $F_{x3} > F_{x1} > F_{x2}$, therefore, submunition 3 is expected to separate first.

To determine the drag coefficients in the fully separated state, a similar CFD-based aerodynamic simulation was performed for each individual sub-projectile (Figure 6).

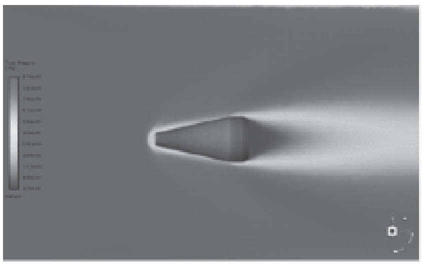


Figure 6. Pressure contours for submunition 1 in the post-separation stage.

The simulated pressure field around the sub-projectile exhibits the characteristic distribution of high-speed flow. A high-pressure region forms at the nose due to flow compression, indicating a peak in pressure at the stagnation point. Downstream, the pressure decreases rapidly as the flow accelerates along the surface, followed by the formation of a low-pressure region in the base area, characteristic of flow separation and wake development. The recessed base configuration promotes the formation of a low-pressure zone, thereby increasing pressure drag due to the significant pressure difference between the forebody and the base of the sub-projectile.

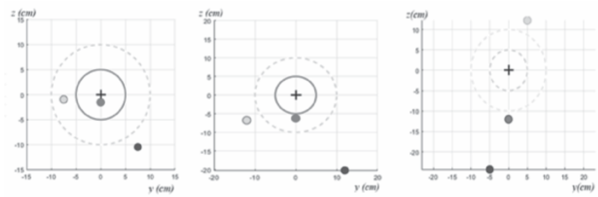
Calculated average drag coefficients of the sub-projectiles in the pre-separation and post-separation stages (Table 2).

Table 2. CFD-predicted average drag coefficients C_{xi} of the sub-projectiles.

Average drag coefficient	Value	
	Pre-separation	Post-separation
C_{x1}	0.38	0.45
C_{x2}	0.18	0.6
C_{x3}	0.63	0.6

4.2. Results of Numerical Simulation of Impact Point Coordinates

Calculated impact point coordinates for a muzzle velocity of v_o = 550 m/s (Figure 7).



a) Range: 50m b) Range: 75m c) Range: 100m
Figure 7. Impact point distribution.

The results indicate that the spatial distribution of impact points of the sub-projectiles is strongly dependent on the firing range. The maximum lateral separations between the sub-projectiles, measured on a plane perpendicular to the line of fire at ranges of 50 m, 75 m, and 100 m, are 17 cm, 26 cm, and 40 cm, respectively.

At a range of 50 m, the impact points remain concentrated near the aiming point with minimal dispersion, as the cumulative effects of aerodynamic drag and divergence angle are still limited. As the range increases to 75 m, the distribution area expands noticeably, and the sub-projectiles separate further, particularly in the lateral direction, reflecting differences in aerodynamic characteristics and velocity decay.

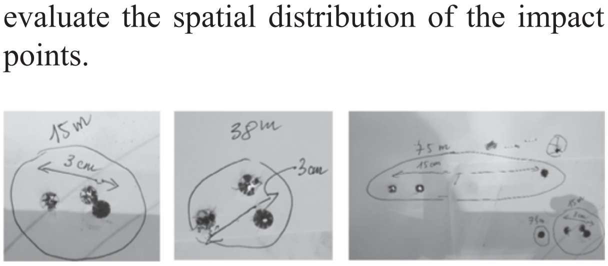
At 100 m, the divergence becomes more pronounced, with the impact points distributed over a wider area in both directions. The vertical deviation increases due to gravitational effects over the flight time, while the lateral deviation is primarily governed by the initial divergence angle.

These results confirm that multi-projectile rounds are capable of expanding the impact area and demonstrate that the spatial distribution can be controlled by adjusting the separation angle and the aerodynamic properties of the individual sub-projectiles.

4.3. Experimental Firing Results

Prototype rounds were fabricated and experimentally tested to validate the separation capability of the sub-projectiles under realistic firing conditions. The primary objectives were to determine the number of separated sub-projectiles and to characterize their dispersion as a function of firing range, based on the analysis of impact points on target surfaces.

Preliminary firing tests were conducted at ranges of 15 m and 38 m to observe and evaluate the spatial distribution of the impact points.

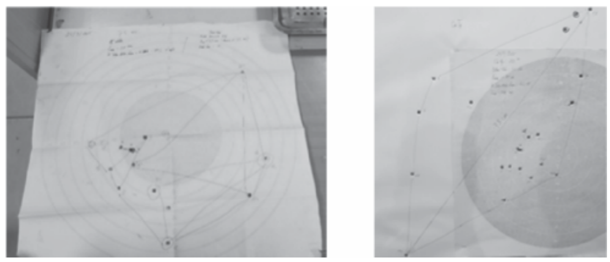


a) Range: 15m b) Range: 38m c) Range: 75m

Figure 8. Preliminary firing test results of impact points

The preliminary firing results for individual rounds at various ranges indicate that the dispersion remains minimal at distances under 38 m. The impact points of submunitions from each individual shot are contained within a circle with a radius of 3 cm. Due to their identical structural design, submunitions 2 and 3 exhibit impact coordinates in close proximity to each other. As the range increases, the distribution area of the impact points expands accordingly, reaching 15 cm at a range of 75 m. All preliminary firing results confirm that the submunitions achieve complete separation.

The results of burst firing tests (5–6 rounds) conducted at ranges of 75 m and 100 m are presented in Figure 9.



a) Range: 75m b) Range: 100m

Figure 9. Impact point distribution of shot groups.

The experimental results demonstrate that in all test firings, each projectile successfully separated into three distinct submunitions after exiting the muzzle, resulting in three independent impact points on the target.

For the 5-round group at a range of 75 m, 15 impact points were recorded within a circle with a diameter of 37 cm. For the 6-round group at 100 m, 18 impact points were recorded within a 75 cm diameter circle. The maximum dispersion area reached 75 cm at 100 m to create a coverage grid, whereas this parameter was only 37 cm at 75 m. This reduction in dispersion area is directly proportional to the expansion of the dispersion cone in external ballistics: at ☞

shorter ranges, the submunitions have not yet drifted far from the central trajectory due to the initial lateral separation impulse.

Consequently, with the proposed design, the submunitions achieve complete separation and generate three times the number of impact points compared to conventional ammunition. The impact distribution within a 75 cm diameter at 100 m creates a "fragment cloud" capable of effectively neutralizing modern small, low-altitude, and highly maneuverable UAV targets.

5. CONCLUSIONS

The study has proposed and developed a multi projectile design configured in a tandem arrangement, compatible with AK, STV380, and STV215 assault rifles. Computational and simulation results demonstrate that upon separation, this configuration forms a "fragment cloud", tripling the number of impact points compared to conventional single-projectile ammunition, thereby significantly expanding the target coverage area. At a range of 100m, the submunitions distribute within a 75cm diameter circle, enhancing the probability of kill against small targets, particularly short-range UAVs.

A comparison between the theoretical and experimental results shows a consistent trend in distribution and motion patterns; however, certain discrepancies remain. These errors primarily stem from the simplification of the aerodynamic model (assuming constant drag coefficients over time and Mach numbers), as well as the exclusion of projectile oscillations, manufacturing and assembly tolerances, and real-world atmospheric turbulence.

The research findings confirm the feasibility of the proposed design and its potential for practical application. Furthermore, this study serves as a scientific foundation for further refining models, optimizing structural parameters, and improving accuracy in developing counter-UAV solutions for modern combat environments.❖

References:

[1]. L. M. Schwartz, J. R. Feddersen, "*Advanced Small Arms Ammunition for Counter-UAS Applications*". Journal of Defense Technology, vol. 19, no. 2, pp. 145-158, 2023.

[2]. A. V. Kuznetsov, D. A. Petrov, "*Development of Multi-Projectile Ammunition for Small Arms*". Russian Engineering Research, vol. 43, no. 5, pp. 412-418, 2023.

[3]. Rostec, "*New Close-Range Anti-Drone Ammunition for Small Arms*". Press Release, 2024.

[4]. J. L. Smith, R. K. Gupta, "*Ballistic Modeling of Fragmenting Projectiles with Aerodynamic Interaction*". Defence Science Journal, vol. 72, no. 4, pp. 389-398, 2022.

[5]. NATO Science and Technology Organization, "*Ballistics and Vulnerability of UAV Systems*". Technical Report STO-TR-AVT-321, 2022.

[6]. M. J. Anderson, "*Modern Exterior Ballistics of Small Caliber Projectiles*". Progress in Aerospace Sciences, vol. 131, 2022.

[7]. R. McCoy, "*Modern Exterior Ballistics: The Launch and Flight Dynamics of Symmetric Projectiles*". Schiffer Publishing, 2019.