

THE VELOCITY AND DIMENSION OF 23MM ANTI-AIRCRAFT ARTILLERY WHEN FIRING

VẬN TỐC VÀ DỊCH CHUYỂN CỦA THÂN PHÁO CAO XẠ 23 MM KHI BẮN

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ABSTRACT

The article presents some basic content about the dynamics of the 23mm cannon, taking into account the efficiency and transmission ratios of the main mechanisms in automatic machines, which are the locking platform, the barrel lock, reload, and acceleration. Not only that, but also calculate the cannon speed when recoil and when pushed up, the displacement of the cannon in the firing cycle. To do that, the paper used Maple software to solve the system of differential equations. Solve results can be presented in table or graph form. Research results can be applied to the design, improvement or exploitation of artillery to improve their readiness to fight and defend the Country.

Keywords: 23mm anti aircraft artillery; Interior ballistics; Dynamic; Velocity; Dimension.

TÓM TẮT

Bài báo trình bày một số nội dung cơ bản về động lực học của pháo 23mm có xét đến hiệu suất và tỷ số truyền của các cơ cấu chính trong máy tự động. Các cơ cấu được xét đến là bộ khóa, khóa nòng, nạp đạn và tăng tốc. Không những thế, bài báo còn tính được tốc độ khâu cơ sở khi lùi và khi đẩy lên, độ dịch chuyển của pháo trong chu kỳ bắn. Bài báo đã sử dụng phần mềm Maple để giải hệ phương trình vi phân. Kết quả giải có thể được trình bày dưới dạng bảng hoặc biểu đồ. Kết quả nghiên cứu có thể ứng dụng vào thiết kế, cải tiến hoặc khai thác các loại pháo phòng không, nhằm nâng cao khả năng sẵn sàng chiến đấu bảo vệ Tổ quốc.

Từ khóa: Pháo phòng không 23mm; Thuật phóng trong; Động lực học; Vận tốc; Quỹ đường.



1. INTRODUCTION

The 23mm anti-aircraft cannon is heavily used in the Vietnamese army as well as in many countries around the world. This one belongs to the type of low-altitude anti-aircraft artillery. Cannons can be single-barreled, dual-barreled or more. However, the basic cannon body has the same structure. The body of the cannon when fired can fluctuate a short distance of less than 1.5 cm to 2 cm. The cannon operates automatically on the principle of extracting gas, locking the barrel with a vertical key.

Residual energy dissipation mechanisms include spring pushback, rear shock absorber disc spring, shock absorber... This article presents the content of surveying automatic machine dynamics and cannon body dynamics when firing. Input data used for calculation are taken according to documents [2], [3]. Systems of differential equations are solved using specialized software for weapons written in Maple software. While the solution was conducted to calculate the pressure in the cannon barrel, the pressure in the air extraction chamber, the speed of the locking platform, taking that as the basis for calculating the working stages such as locking the barrel, reloading, and accelerating. The results are presented in graph form for convenient observation and evaluation. From the dynamics survey, it is possible to calculate the firing rate and other technical and tactical information. Calculation results are documents to serve the design, exploitation, or improvement of weapons for different purposes.

2. CONTENT

Kinetic investigation of automatic machine mechanisms is to determine the

kinematic characteristics including gear ratio K and efficiency η . Dynamic survey is the study of the movement of parts under the action of force.

2.1. How to determine gear ratio and performance

a. Several methods of determining the gear ratio

- Analytical method: According to the definition of the transmission ratio of the document [1], we have the formula:

$$K_i = \frac{dX_i}{dX} = \frac{V_i}{V} \quad (1)$$

If we find the relation $x = f(x)$ in analytical form, using differential function, we will find the expression to determine the transmission ratio according to formula (1). If we can find the expression for determining the speed of the base link V (bolts) and the working link V_i , we can also find the expression for determining the gear ratio according to the above formula.

- Graph differential method.

If we know the graph representing the relationship $x = f(x)$, using the graph differential method, we can find the graph $K = dx / dx$.

- Method of plotting velocity combined with solving graph:

Velocity plotting is a method to determine the speed of the links in the mechanism during motion, especially the end. It has the advantage that the structure is complex, the calculation volume is not large,

and the drawing method is simple. Combining speed plotting with plotting, determining the gear ratio graph will be quite fast and simple. But the accuracy depends a lot on the scale, the accuracy of the drawing.

In this paper, the author chooses an analytical method to determine the gear ratios of the mechanisms.

b. Method of determining performance

According to the definition of transmission efficiency between stages, we have:

$$\eta = \frac{R'_B}{R'_A} \cdot K \quad (2)$$

To determine the efficiency of the surface mechanisms between links, it is necessary to determine the gear ratio K , the ratio of the drag forces R'_B and the thrust R'_A . We determine the efficiency of the first-class surface mechanism as follows:

Assume that the influence on the distribution of the bonding reactions, the influence of the position of the force and their deflection are ignored, all forces are assumed to pass through the substitution point of the pieces.

Let R'_A and R'_B be the resultant of the external forces acting on the direction of motion of the links A and B. Write the force balance equation for the links after they have been separated from the connection and substitute for the action of the pieces. These are the binding reactions we have:

For stage A:

$$\begin{aligned} R'_A &= R \cdot (\sin A + f \cdot \cos A) + f \cdot N_1 \\ N_1 &= R \cdot (\cos A - f \cdot \sin A) \end{aligned}$$

Therefore:

$$R'_A = R \cdot (\sin A + 2f \cdot \cos A - f^2 \cdot \sin A)$$

For stage B:

$$\begin{aligned} R'_B &= R \cdot (\cos A - f \cdot \sin A) - f \cdot N_2 \\ N_2 &= R \cdot (\sin A + f \cdot \cos A) \end{aligned}$$

By the definition of efficiency we have:

$$\eta = \frac{R'_B}{R'_A} \cdot K = \frac{1 - 2f \cdot K - f^2}{K + 2f - f^2 \cdot K} \cdot K$$

Ignoring the quantity containing f^2 , we get:

$$\eta = \frac{1 - 2f \cdot K}{K + 2f} \cdot K \quad (3)$$

2.2. Calculation of gear ratios and efficiency of mechanisms in a 23mm cannon

a. Lock-barrel pedestal drive pair

The 23mm anti-aircraft gun bolt is an automatic vertical key type, the opening and closing of the bolt is done automatically to the articulation of the crossbar on the bolt and the diagonal groove on the lock pedestal as shown in Figure 1.

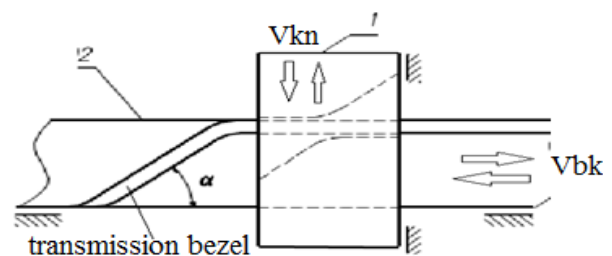


Figure 1. Diagram of the mechanism of opening and closing the bolt

1-Bolt; 2- Lock pedestal; α - Surfaceline tangent angle.

When the platform is in reverse, the unlocking face on the lock pedestal moves into the unlocking face on the bolt, to the low position, the bolt is lowered to unlock it. When

the lock is closed, the above process is reversed. The opening and closing transmission of the 23 mm cannon is a type I surface. This is a surface with a double-sided link.

The transmission ratio of the opening and closing mechanism is determined by the formula:

$$K_{mk} = \frac{dx_i}{dx} = \frac{V_i}{V} = \tan \alpha$$

The efficiency of the opening and closing surface is determined by the formula:

$$\eta_{mk} = \frac{1 - 2.f.K_{mk}}{K_{mk} + 2.f} K_{mk} \quad (4)$$

With : $f=0.1$: Coefficient of transmission friction.

Measurements on the actual structure and calculations based on the reference data in the document [3], we get the results of the gear ratio and the efficiency of the opening and closing mechanism as follows:

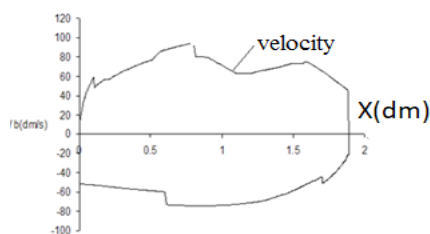


Figure 2. Graph of lock pedestal's velocity on distance

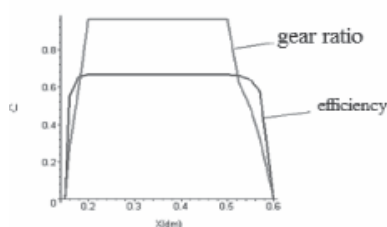


Figure 3. Graph of efficiency and gear ratio of the lock pedestal -bolt

b. Acceleration-ejection transmission

Accelerate the withdrawal of the cartridge case when the padlock is inverted and accelerate the bullet to force the bullet into the chamber before closing. These functions are accomplished by means of the surface on the accelerator and the surface on the cannon.

The 23mm anti-aircraft gun accelerator is a dual drive mechanism consisting of two links:

- The linkage between the accelerator and the acceleration base is equivalent to a non-standard type IV surface, with the feature that the linkage shaft is located on the base link and the surface profiles when reversing and pushing up are different.

With $\alpha = 90$ on the real structure, we have the formula to calculate the transmission ratio and the efficiency of this link as follows:

$$K_4 = 1 + \frac{r_b}{r_c} \cdot \frac{\sin \alpha \cdot \cos \varphi}{\sin(\alpha + \theta)}$$

$$\eta_4 = \frac{1 + f \cdot \cot g(\alpha + \theta)}{(1 + f \cdot \cot g(90^\circ + \varphi)) \cdot (1 + 2.f \cdot \cot g \alpha)} \quad (5)$$

- The link between the accelerator lever and the ejection lever is a type four surface link. However, due to the simple structure and small firing angle, the motion directions are parallel to each other, so we can calculate the kinematic characteristics of the mechanism by the following simple correction formula:

$$\text{We have: } K = \frac{dS}{dX};$$

$$\text{So that: } \Delta K = \frac{r_m \cdot (|\cos \gamma_i| - |\cos \gamma_{i-1}|)}{\Delta x};$$

Summarizing the two links, we have:

$$K_{gt} = K_4 + \Delta K = 1 + \frac{r_b}{r_c} \cdot \frac{\sin \alpha \cdot \cos \varphi}{\sin(\alpha + \theta)} + \frac{r_m \cdot (|\cos \gamma_i| - |\cos \gamma_{i-1}|)}{\Delta x}$$

$$\eta_{gt} = \eta_4 = \frac{1 + f \cdot \cot g(\alpha + \theta)}{(1 + f \cdot \cot g(90^\circ + \varphi)) \cdot (1 + 2 \cdot f \cdot \cot g \alpha)}$$
(6)

Summarizing the two links we have:

With: $f = 0.1$ - coefficient of friction. α , θ , γ , ϕ : are shown in the figure.

Measure on the real structure and calculate the results of the gear ratio and the efficiency of the accelerator as shown in Figure 5.



Figure 4. Diagram of acceleration mechanism
1- Eject bullets pice; 2- Accelerometer pice;
3-Surface.

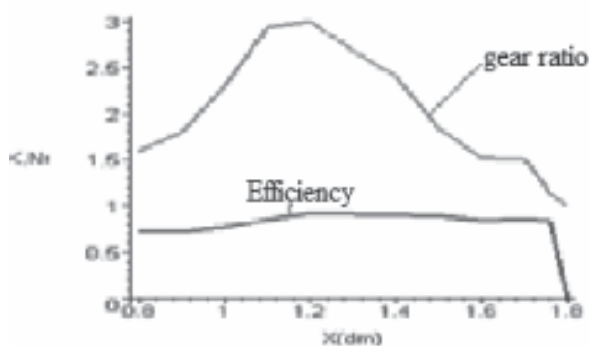


Figure 5. Efficiency, gear ratio of the accelerator

c. Ammunition mechanism

The reloading mechanism is responsible

for bringing the next bullet from the reloading position to the loading position, ready to fire. During the push-up stroke, the bullet lever presses against the side surface face to run to the position to wait for ammunition. The 23mm cannon feed mechanism is a drive mechanism consisting of two links:

- The link between the rack and the tooth is a surface link of the first type, with a constant surface side angle with a double-sided connection.

The formula for calculating the gear ratio and efficiency of this surface link is as follows:

$$K_1 = \tan \alpha ; \eta_1 = \frac{(1 - 2 \cdot f \cdot K) K}{K + 2 \cdot f}$$
(7)

- The link between the loading table and the sliding frame is a non-standard type IV surface with two special points:

- + In this surface mechanism, the intermediate boom shaft moves in translation with a fixed surface profile.

- + When reversing and pushing up, the connection is made on two different surface profiles with different coefficients of friction: when reversing is rolling friction, when pushing up is sliding friction.

On the real structure, with $\alpha = 90$, we have the formula to calculate the transmission

ratio and the efficiency of this link as follows:

$$K_4 = \frac{r_b}{r_c} \cdot \frac{\sin \alpha \cdot \cos \varphi}{\sin(\alpha + \theta)};$$

$$\eta_4 = \frac{1 + f \cdot \cot g(\alpha + \theta)}{(1 + f \cdot \cot g(90^\circ + \varphi)) \cdot (1 + 2 \cdot f \cdot \cot g \alpha)} \quad (7)$$

In general, when the intermediate axis moves, we have the following correction formula:

$$K'_4 = \frac{V_\psi}{V_A} = \frac{V_1 \cdot \sin \psi + V_4 \cdot \cos \psi}{V_A}$$

$$= K_1 \cdot \sin \psi + K_4 \cdot \cos \psi \quad (8)$$

Summarizing the two links, we have:

$$K_{td} = K_1 \cdot K'_4; \eta_{td} = \eta_1 \cdot \eta'_4 \quad (9)$$

Measuring on the real structure and combining calculations, we get the results of the gear ratio and efficiency at different times, of the feed mechanism corresponding to the displacement of the locking platform.

Measurements on cannons and calculation, results are shown in Figure 7.

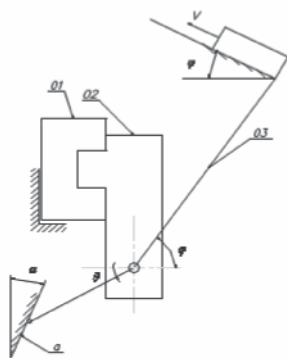


Figure 6: Diagram of the principle of the reloading mechanism

01- Reload slider; 02- Slide table; 03- Push lever

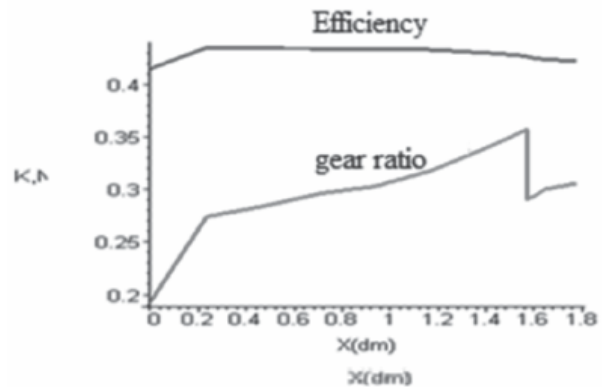


Figure 7: Efficiency and transmission ratio of the reloading mechanism

2.3. Dynamics 23mm cannon

After studying the 23mm cannon kinematics, continue to investigate the cannon reverse block dynamics when firing.

The content of solving the system of equations of motion of the automatic machine is to determine the laws $V=V(x)$ and $t=t(x)$ of the base and some working stages of the automatic machine, as well as determine its duty cycle, from which to evaluate, cannon body price fluctuates in a cycle. Things to do include:

-Actual force: including the force of the gas in the barrel, the force of the gas extracted in the air chamber, the force of the spring pushing back...;

-Determine the collapsing volume, collapsing force;

-Collision between details;

-Interpolation function: use linear interpolation;

-Method to solve system of differential equations: Runge-Kuta;

- Input data set: according to documents [3], [4].

The displacement of the cannon in one shot cycle is 1.5 cm. If the cannon moves longer, it will be quieter, but the rate of fire will decrease, which is detrimental to anti-aircraft guns.

The maximum speed of the cannon is approximately 24 dm/s, the greater the speed, the shorter the firing cycle, but the large end-of-stroke collision can reduce the accuracy of the shot.

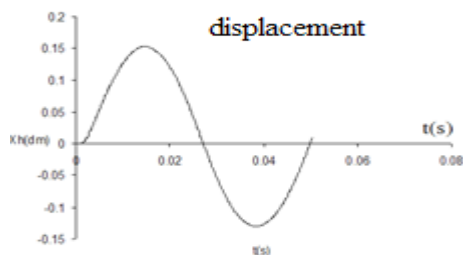


Figure 8: Graph of displacement of the 23mm cannon in one cycle

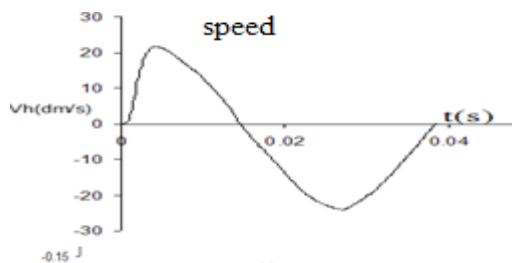


Figure 9: Graph of speed of the 23mm cannon in one cycle

3. CONCLUSION

The article investigated the speed and displacement of the 23mm anti-aircraft cannon backward and forward in one shot cycle. The results are relatively close to the results of previous scientific publications, which proves that the system of equations, calculation methods, and parameters are relatively reliable. The above calculation results can be applied to similar weapons in the process of designing, manufacturing, improving or exploiting weapons at the military base. ❖

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