STUDYING THE EFFECT OF BULLET BELT DRAG ON THE AUTOMATIC MACHINE MOVEMENT OF 23MM ANTI-AIRCRAFT GUNS

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ABSTRACT

In this paper, the equation for determining the resistance of the belt according to the number of bullets and the wave propagating on the bullet belt is established. The results of the investigation of the dynamics problem of the 23mm anti-aircraft gun when taking into account the change in belt resistance are as follows: Corresponding to the number of bullets of 10, 20, and 30 rounds on the bullet belt, the resistance of the bullet belt increases by 2%, 5%, 8%, respectively, the movement period of the barrel is reduced by 3.2%, 2.9%, 2.4%. The research results of the article are an important theoretical basis for calculating and designing automatic machines, ammunition belts and ammunition mounting devices for automatic cannons loaded with belt.

Keywords: *The bullet belt; Belt resistance; Gear ratio and efficiency; Anti-aircraft gun.*

TÓM TẮT

Trong bài báo này, phương trình xác định lực cản băng đạn theo số lượng viên đạn và sóng lan truyền trên dây băng được thiết lập. Kết quả khảo sát bài toán động lực học của pháo phòng không 23mm khi kể đến sự thay đổi lực cản băng đạn như sau: Tương ứng với loạt bắn là 10, 20, 30 viên đạn thì lực cản dây băng tăng tương ứng 2%, 5%, 8%, chu kì chuyển động của bệ khóa nòng giảm 3.2%, 2.9%, 2.4%. Kết quả nghiên cứu của bài báo là cơ sở lý thuyết quan trọng để tính toán, thiết kế máy tự động, dây băng đạn và thiết bị lắp đạn cho pháo tự động nạp đạn bằng dây băng.

Từ khóa: *Dây băng đạn; Lực cản dây băng; Tỷ số truyền và hiệu suất; Pháo phòng không.*

1. INTRODUCTION

Anti-aircraft gun ЗУ-23-2 works automatically on the principle of gas extraction, open air chamber, long recoil piston. So, in the process of igniting, a part of the combustible gas is extracted through the barrel wall to create energy to make the automatic parts on the cannon work, one of the important parts of the automatic machine of the cannon is the bullet loading mechanism.

The reloading mechanism is used to feed the belt into the belt door and direct the bullet when it is loaded into the ammunition chamber. The ammo belt is a semi-soft tape with open links. Therefore, the bullet belt creates waves that propagate in the opposite direction to the direction of the belt's motion when firing, which is the cause of the resistance to the belt's movement. This resistance changes the working cycle of the automatic machine, thereby changing the rate of fire of the cannon. In the world, there have been many studies on the movement of the belt [1], but these studies only focus on the law of motion of the belt, but there has not been any research to study its impact on the working process of automatic machine. TIn the framework of the paper, the equation for determining the law of belt resistance has been established. The working parameters of the automatic machine were investigated according to the change of the belt resistance.

2. ESTABLISHING A COMPUTATIONAL MODEL

2.1. Determination of belt resistance [2]

To determine the belt resistance, several assumptions are used as follows::

- The belt belt is considered to be absolutely hard;

- Ignore the gap between the belt links;

- The mass of the belt is evenly distributed over its length;

- The law of waves traveling on a belt has the form: $u_x = \varphi(t - \frac{l-x}{a})$

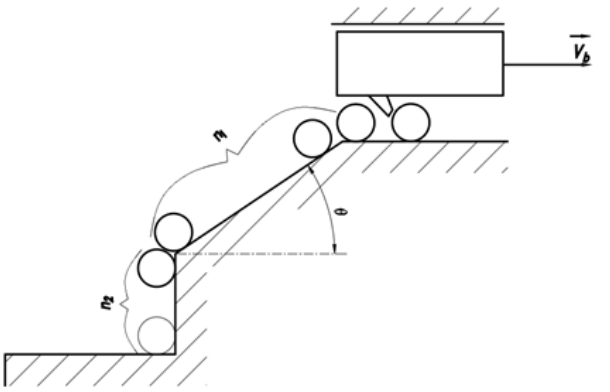

Figure 1. General belt belt model

Let P be the resistance of the belt created by the incident wave.

$$P = E\frac{\partial u_x}{\partial x} = E\frac{\partial}{\partial x}\left[\varphi\left(t - \frac{l-x}{a}\right)\right] = E\frac{\partial}{\partial x}\varphi\left(t - \frac{l-x}{a}\right).\varphi_t'\left(t - \frac{l-x}{a}\right) \quad (1)$$

Where:

$$\varphi_t'\left(t - \frac{l-x}{a}\right) = V_x;\ \frac{\partial}{\partial x}\varphi\left(t - \frac{l-x}{a}\right) = \frac{1}{a};$$

V_x is the instantaneous speed of the belt's cross-section at coordinates x.

The formula for calculating the gear ratio and efficiency of the bullet loading mechanism is as follows [3]:

$$K_{td} = tg\alpha.\frac{r_b}{r_c}.\frac{\sin\alpha.\cos\phi}{\sin(\alpha+\theta)} \quad (2)$$

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$$\eta_{td} = \frac{(1-2.f.K_{td}).K_{td}}{K_d + 2.f} \cdot \frac{1 + f.\cot g(\alpha+\theta)}{(1+f.\cot g(90^0+\phi)).(1+2.f.\cot g\alpha)} \quad (3)$$

After the transformation, the belt resistance taking into account the weight of the belt and the friction force on the slide is as follows:

$$P_b = K_b\sqrt{K\mu}.V_b.K_{td} + n_1\mu g\left(\sin\theta + f\cos\theta\right) + n_2\mu g \quad (4)$$

n_1 is the number of bullets lying on the inclined plane with an angle θ;

n_2 is the number of bullets hanging in the ammo box;

f is the coefficient of friction;

K is the belt's hardness;

μ is the mass of the belt eye;

V_b is the velocity of the bolt carrier;

K_b is the factor that takes into account the difference in force between the belt links.

2.2. ESTABLISHING THE SYSTEM OF DIFFERENTIAL EQUATIONS OF MOTION OF AUTOMATIC MACHINES

Some of the assumptions used are as follows [4]:

- Except for springs and elastic parts, other links are considered to be absolute solids, dynamically linked with each other, with variable or constant transmission ratios.;

- Use collapsed mass instead of distributed mass. The collapsing mass setpoint can be arbitrary, usually the two-way contact point or the set point of the applied external force.

The physical model of the automaton can be represented as follows:

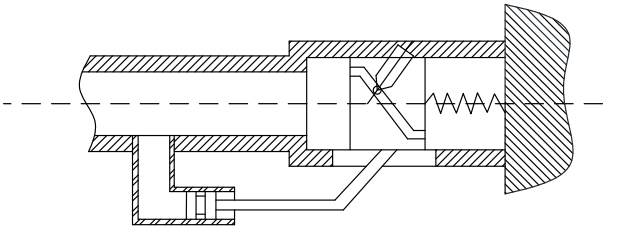

Figure 2. Physical model of the automaton

The automatic machine motion division equation can be obtained by mechanical analysis using Lagrangian equation type II.

According to [1], the system of equations of motion of the automatic machine is as follows:

$$\begin{cases} \left(M_b + \sum_{i=1}^{n}\frac{K_i^2}{\eta_i}\varepsilon_i m_i\right)\frac{dv_b}{\eta_i} + \sum_{i=1}^{n}\frac{K_i}{\eta_i}\varepsilon_i m_i v_b^2\frac{dK_i}{dl_b} = \xi_5\left(F_b - \sum_{i=1}^{n}\frac{K_i}{\eta_i}\varepsilon_i F_i\right) \\ \frac{dl_b}{dt} = \xi_5 v_b \end{cases} \quad (5)$$

Where: M_b, v_b - Mass and velocity of base part; l_b - Movement distance of base part; K_i, η_i - Transmission ratio and efficiency of the second working part i; F_b - External force acting on the base part; F_i - External force acting on the working part i;

The system of equations (2.70) can be abbreviated as follows:

$$\begin{cases} M_{11}\ddot{l}_b + M_{12}\dot{l}_b^2 = P_A \\ \frac{dl_b}{dt} = v_b \end{cases} \quad (6)$$

$M_{11} = M_b + \sum_{i=1}^{n} m_i\frac{K_i^2}{\eta_i}$ - Collapsed mass of the system at the base part; $M_{12} = \sum_{i=1}^{n} m_i\frac{K_i}{\eta_i}\frac{dK_i}{dl_b}$ - Secondary force of inertia; $P_A = F_b - \sum_{i=1}^{n}\frac{K_i}{\eta_i}F_i$ - Collapsed force of the system. ☞

3. INVESTIGATE THE EFFECT OF BELT RESISTANCE ON AUTOMATIC MACHINE MOVEMENT

3.1. Determination of gear ratio and efficiency of the bullet loading mechanism

With the actual construction parameters, the results of the gear ratio and the efficiency at different times of the bullet loading mechanism according to the displacement of the bolt carrier are determined as follows:

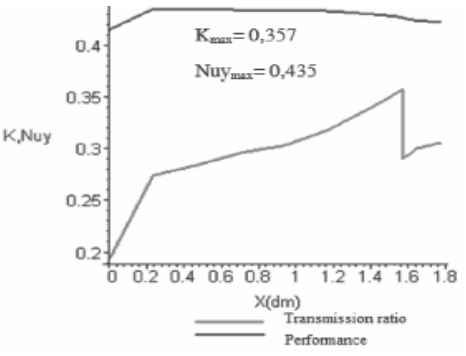

Figure 3. Gear ratio and performance in reverse bolt carrier

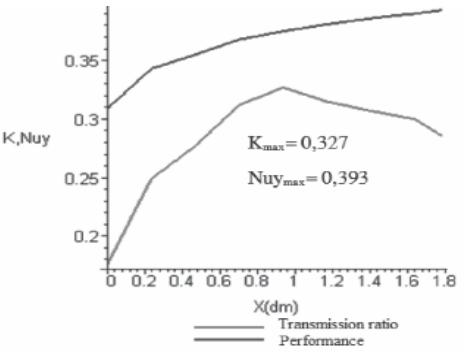

Figure 4. Gear ratio and efficiency when the bolt carrier is pushed up

3.2. Investigate the effect of belt resistance on automatic machine movement

The results of calculating the belt resistance according to the movement of the bolt carrier are shown in the following table:

Table 1. Belt resistance when the bolt carrier is reversed

x	0	23.4	46.8	70.3	93.7	117.1	140.5	157	164	178
$\mathbf{K_{td}}$	0.193	0.274	0.284	0.296	0.303	0.318	0.340	0.290	0.299	0.306
$\boldsymbol{\eta_{td}}$	0.415	0.435	0.435	0.434	0.434	0.433	0.430	0.426	0.424	0.422
P	39.2	39.8	40.3	40.9	41.4	42.2	43.8	40.3	41.1	41.6

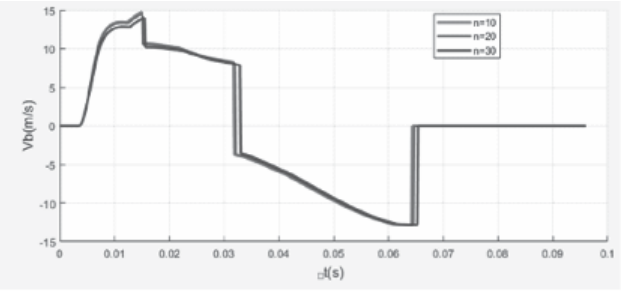

Figure 5. Graph of the barrel velocity corresponding to the number of bullets on the belt

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Table 2. Belt resistance when the bolt carrier is pushed up

x	178	164	157	140.5	117.1	93.7	70.3	46.8	23.4	0
$\mathbf{K_{td}}$	0.286	0.300	0.302	0.307	0.315	0.327	0.312	0.277	0.249	0.176
$\boldsymbol{\eta_{td}}$	0.393	0.390	0.389	0.386	0.381	0.375	0.368	0.355	0.343	0.309
P	28.5	29.1	29.9	30.5	31.2	32.6	31.5	28.2	26.5	22.1

Comment:

From the results in Tables 1, 2 and Figure 6, it is shown that:

- The belt drag varies with the gear ratio and the efficiency of the belt construction. In addition, the number of bullets on the belt also significantly affects the resistance of the belt.

- With the number of bullets on the belt is 10, 20, 30 rounds, the firing period is 0.06465s, 0.06480s, 0.6570s and the rate of fire is 932; 928; 917 plays/minute.

4. CONCLUSION

In this paper, the equation for determining the resistance of the belt has been established. The belt resistance is determined by the number of bullets on the belt. Corresponding to the number of bullets on the belt of 10, 20, 30 rounds, the velocity law of the bolt carrier is determined. With this result, some conclusions are made as follows:

- The belt resistance is an important parameter that needs to be determined when solving the automatic machine dynamics problem of the cannon using the belt.;

- The belt resistance depends mainly on the number of bullets on the belt and the incident wave.

- The effect of belt resistance is not great with automatic machines movement. However, the rate of fire is an important factor for anti-aircraft guns, so it is necessary to study the effect of belt resistance on the operation of automatic machines.❖

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