DYNAMIC SURVEY OF AUTOMATIC GUNS WHEN MOUNTED ON MOBILE VEHICLES

KHẢO SÁT ĐỘNG LỰC CỦA SÚNG TỰ ĐỘNG KHI LẮP TRÊN PHƯƠNG TIỆN CƠ ĐỘNG

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ABSTRACT

The article presents a survey model and research results on the dynamics of automatic guns when mounted on mobile vehicles. Based on the specific installation plan of the gun on the combat robot, authors has built a mathematical model describing the dynamics of the gun-carrier system when firing. Based on the system of differential equations of motion, combining the system of internal launch equations and the system of thermodynamic equations of the gas chamber, simulation calculations are conducted using Matlab software. The results obtained are the basis for making recommendations to improve the firing efficiency of automatic weapons when installed on mobile vehicles.

Keywords: *Combat robot; Dynamics; Automatic gun; Recoil reduction; Stability; Shooting accuracy.*

TÓM TẮT

Bài báo trình bày mô hình khảo sát và kết quả nghiên cứu về động lực học của súng tự động khi lắp trên xe cơ động. Trên cơ sở phương án lắp súng cụ thể trên rô bốt chiến đấu, tác giả đã xây dựng mô hình toán học mô tả động lực học của hệ thống giá-súng khi bắn. Trên cơ sở hệ phương trình vi phân chuyển động, kết hợp hệ phương trình thuật phóng trong và hệ phương trình nhiệt động lực học buồng khí, tiến hành tính toán mô phỏng bằng phần mềm Matlab. Kết quả thu được là cơ sở đưa ra các khuyến nghị nhằm nâng cao hiệu quả bắn của vũ khí tự động khi lắp trên xe cơ động.

Từ khóa: *Robot chiến đấu; Động lực học; Súng tự động; Cơ cấu giảm giật; Ổn định; Độ chính xác bắn.*

1. INTRODUCTION

Nowadays, along with the advances of science and technology in all areas of social life, achievements in the field of military science have had many enormous applications, especially technologies that allow to minimize the presence of humans on the battlefield. Installing automatic guns on mobile vehicles (combat robots) is a trend to carry out tasks to ensure human safety in special combat spaces. In this case, factors related to the dynamics of the weapon-robot system must be taken into account when firing. The guns in current equipment mainly operate on the principle of gas extraction, so the connection between the gun and the robot is often through a recoil reduction mechanism. The structure of the recoil reduction mechanism ensures that the load acting on the stable mount when firing as well as ensuring the accuracy of the gun's shooting during combat.

2. COMBAT ROBOTS AND THE DYNAMICS OF AUTOMATIC GUNS WHEN MOUNTED ON COMBAT ROBOTS

2.1. Structure of the fighting robot

The combat robot consists of two main parts: the moving part and the weapon mounting part. To be highly effective in combat missions, the robot must ensure flexibility, the ability to move and maneuver well on complex terrain. In addition, to be able to fight effectively, the robot's weapon mounting part must have a reasonable structure, ensuring the stability of the weapon when firing. The remote-controlled combat robot uses a camera for automatic guns and is designed to include the following structural clusters (Figure 1): the vehicle body, gun mount, control and power block, remote loading and firing control mechanism cluster for machine guns and auxiliary equipment cluster.

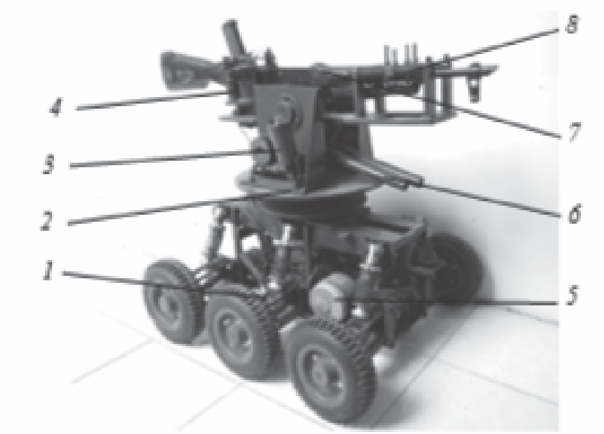

Figure 1. Mounting an AK submachine gun on a combat robot:
1 - Vehicle body; 2 - Gun mount; 3 - Rotation motor; 4 - Loading and firing assembly; 5 - Wheel drive motor; 6 - Balancing mechanism; 7 - AK submachine gun; 8 - Recoil reduction assembly

The body of the vehicle uses a reasonably structured frame system, ensuring rigidity. The robot moves on wheels to ensure high mobility and flexibility in use. The wheels are driven by electric motors, operating through relays that are remotely controlled by control signals from the command center.

The gun mount includes a recoil reduction mechanism connecting the dynamic part and the static part, a part connecting the gun to the mount, a mounting base for the target observation camera, a range-aiming part, a magazine and other mechanisms. The recoil reduction mechanism uses a recoil reduction spring with coplanar axes, parallel to the barrel axis. So the force of the shot through the recoil reduction mechanism is reduced, partly transmitted to the upper base and through two trough shafts acting on the lower base. The target observation camera mounting base is designed to be mounted on the mount to reduce the direct impact of the shot force and increase the stability of the camera during aiming. The vertical rotation mechanism is designed with a gear type, a toothed arc combined with a screw shaft, a worm gear. The horizontal rotation mechanism is a screw shaft, a worm gear with a dirt removal mechanism in type compression spring type. The vertical and horizontal rotation mechanism is controlled by electric motors with small module transmissions to help rotate in the vertical and horizontal smoothly.

In the control and power block, control relays, robot controllers and gun mount controllers are arranged along with motor amplifiers. The battery power supply is arranged in a separate compartment. The remote loading and firing control mechanism cluster for the machine gun is remotely controlled by control signals from the command center. The cluster of auxiliary equipment including remote target detection cameras, laser rangefinders, ballistic computers, control panels, multi-function displays, signal transmitters, etc. are arranged in the command center.

2.2. Dynamic model of automatic gun on combat robot

With the structure of the combat robot and the automatic gun based on the gas extraction principle, it is possible to build a physical model and a mathematical model of the system as an automatic gun system with the gas extraction principle linked to the mount through a recoil reduction mechanism (Figure 2) [1].

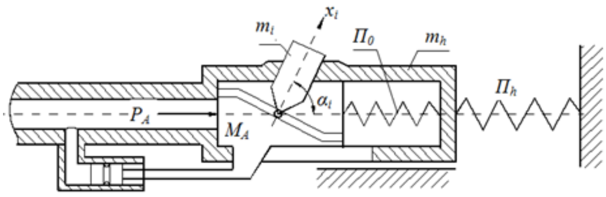

Figure 2. Schematic diagram of the working principle of an automatic machine based on the gas extraction principle with a recoil reduction mechanism mounted on a combat robot:
P_A - Gas pressure; M_A - Breech mass; m_h - Breech block mass;
Π_h - Potential energy of recoil reduction assembly; Π_0 - Potential energy of the spring; m_i - Mass of work parts; α_i - Angle between the direction of movement of the work parts and the barrel axis

Using the Lagrange equation of the second kind [2]:

$$\frac{d}{dt}\left(\frac{\partial \mathrm{T}}{\partial \dot{q}_i}\right)-\frac{\partial \mathrm{T}}{\partial q_i}+\frac{\partial \Pi}{\partial q_i}=Q_i \;,(\,j=1,2\,) \quad (1)$$

Where: T, Π - The kinetic and potential energy of the system; q_i, $\dot{q}_i$ - The extension coordinates and extension speed; Q_i - The extension force; t - Time; j - Number of degrees of freedom.

In extension coordinates, take $q_1 = x$ and $q_2 = x_h$.

Calculate the kinetic energy and potential energy of the system, then take the partial derivatives with respect to the corresponding variables and substitute into (1), we get the equation of motion of the system:

$$\left.\begin{aligned} M'_A+\dot{x}^2 M_{qt}+M_\eta \ddot{x}_\eta &= P'_A - C_A x; \\ M_K \ddot{x}+\dot{x}^2 M_i + M_h \ddot{x}_h &= P'_h - C_h x_h. \end{aligned}\right\}$$

In there:

$$M'_A = M_A + \sum_{i=1}^{n} \frac{K_i^2}{\eta_i} m_i;$$

$$M_h = M_A + m_h + \sum_{i=1}^{n} m_i;$$

$$M_{qt} = \sum_{i=1}^{n} \frac{K_i}{\eta_i} m_i \frac{dK_i}{dx};$$

$$M_\eta = M_A + \sum_{i=1}^{n} \frac{K_i}{\eta_i} m_i \cos\alpha_i$$

$$M_K = M_A + \sum_{i=1}^{n} K_i m_i \cos\alpha_i;$$

$$M_i = \sum_{i=1}^{n} K_i m_i \cos\alpha_i \frac{dK_i}{dx};$$

$$P'_A = P_A - \Pi_{A0} - \sum_{i=1}^{n} \frac{K_i}{\eta_i} P_i;$$

$$P'_h = P_h - \Pi_{h0} - \mathrm{sign} x_h - F \mathrm{sign} \dot{x}_h.$$

$$\mathrm{sign} x_h = \begin{cases} 0 \quad \text{when} \quad x_h = 0, \\ -1 \quad \text{when} \quad x_h < 0, \\ 1 \quad \text{when} \quad x_h > 0. \end{cases}$$

$$\mathrm{sign} \dot{x}_h = \begin{cases} 0 \quad \text{when} \quad \dot{x}_h = 0, \\ -1 \quad \text{when} \quad \dot{x}_h < 0, \\ 1 \quad \text{when} \quad \dot{x}_h > 0. \end{cases}$$

F - The friction force between the gun body and the slide on the robot's mount.

2.3. Simulation results and discussion

Simultaneously solving the system of differential equations of motion with the internal ballistic equation and the gas chamber thermodynamic equation, we get the result (Figure 3).

We perform calculations for the PKT machine gun with the input data: rear recoil spring stiffness C_g = 40000 N/m, initial compression x_{h0} = 11 mm, fire at gas port number 2. The results are: x_{hmax} = 6,1 mm, the duty cycle of the automatic machine T_{ck} = 76,42 ms is equivalent to the theoretical rate of fire of 735 rounds/min (The firing rate stated in the manufacturer's documentation is 700 - 750 rounds/min) [3, 4]. Thus, the structure of the combat robot ensures that it does not affect the gun's combat performance as well as the load acting on the mount (robot) within the allowable limits.

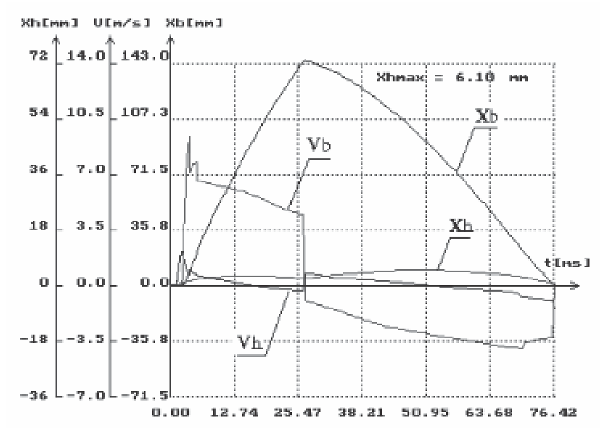

Figure 3. Law of motion of the breech block and the gun frame during the cycle of a shot:
X_b, V_b - The distance, velocity of movement of the breech block;
X_h, V_h - The displacement and velocity of the gun barrel block

3. CONCLUSION

When installing a gun on a mobile vehicle, a combat robot, to ensure the correlation between mobility and shooting accuracy, it is necessary to solve many problems in general. These problems include: the problem of ☞

increasing the capacity of the ammunition box, the ability to operate flexibly and remotely control the shooting of the robot, the problem of the load applied to the robot by the weapon when shooting... The content of the article only mentions a small part of the overall problem to ensure the stability of the weapon-robot system with the goal of ensuring the shooting accuracy of the entire system when shooting.❖

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