Research on Movement Characteristics of Launching Mechanism of Portable Missile Launcher

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Abstract. According to the design requirements of portable missile launchers, the launch mechanism is utilized to provide a structure that can finely adjust the launching angle according to the movement of the target to be attacked. Using the procedure of theoretical calculation and simulation, this dissertation focuses on the key technologies in the design and application of the overall structure of the portable missile launcher, and uses the ADAMS software to simulate the launch mechanism. The launching mechanism model with the secondary clearance of movement is established. The mathematical model of the launcher with clearance is established by Lankarani-Nikravesh method and the movement process of the launching mechanism is simulated by ADAMS dynamic simulation software to test the movement accuracy when the launcher has different clearances. Through the simulation results, it can be seen that there are distinct influences on the movement of the mechanism when there is a movement gap in different positions of the launching mechanism. The simulation results are analysed, and the structure of the launching mechanism is modified according to the analysis results to obtain a better movement condition new launching agency.

1. Introduction
Among the modern army, armed helicopters are playing a more and more important role. Their aggressiveness and ability are being rewritten into the Army's method of fighting [1]. To defend the armed helicopters, researchers developed portable anti-aircraft missiles to attack them [2]. Portable anti-aircraft missiles as a transportable ultra-short-range air defense equipment, some ground forces are the main air defense weapons. In the Gulf War, most of the various types of aircraft were downed by air defense missiles [3]. So the air defense missiles play a key role in the field of contemporary warfare. Resulting from the heavy burden on soldiers and their lack of firepower, the portable shoulder-to-air manned anti-aircraft missile system has evolved in the manner of launching launchers [4]. Since the development of the first portable anti-aircraft missile in 1970[5], many domestic and foreign companies have paid great attention to the related technologies of portable missile launchers. Numerous researches have been conducted on the shooting techniques of portable missiles. In the early 1970s, Bofus Sweden began to develop the RBS-70 series of anti-aircraft missiles and upgraded a portable launcher for launching [6]. Since 1972, General Motors has developed a Stinger anti-aircraft missile system that can launch two missiles at the same time using a portable launcher [7]. In the late 1970s, Russia began producing "pin" type portable anti-aircraft missiles and used them on launchers [8]. In 1980, the French company Matera developed "Northwest Wind" air defense missile system [9], the missile system is easy
to carry, assembly speed, missile speed, mobility. China's QW-18 missile system is China's third-generation portable anti-aircraft missile system, its performance is located at home and abroad leading position [10]. After 40 years of progress, the research on multi-body mechanism has approached maturity. In 2002, Jia from Tsinghua University, does the gap cranks slider mechanism theory and experimental research at the same time, mainly for different crank speed and clearance size of the dynamics analysis of the mechanism [11]. In 2002, Delft University of Technology Schwab et al. studied the linkage mechanism system with both rigid and elastic rods [12] and proposed a measure to effectively eliminate or reduce the contact force. In 2008, Khemili and Romdhane of the Latin American National Laboratory studied the dynamic characteristics of the gap of the flexible crank-slider mechanism through ADAMS simulation and experiments [13]. In 2011, Bai Zhengfeng of Harbin Institute of Technology studied in detail the dynamic characteristics of the lever mechanism considering the regular clearance, irregular clearance and the friction [14]. In 2015, Wang Zhisong and Feng Xianglei of Yanshan University analyzed and experimentally studied the dynamic characteristics of the clearance mechanism. The movement characteristics of the clearance-crank mechanism with clearances and different speed of prime mover were discussed [15]. In this paper, designing the launching mechanism of portable missiles utilizing the principle of space mechanism and simulating and analyzing the space mechanism is necessary. Therefore, research on the launching frame at home and abroad and the research on the space mechanism has great significance to this article.

2. Design of launching mechanism

The transmitting mechanism adopts the polar angle mode to perform the anterior angle adjustment. During the adjustment process, manual and electric operations have to be combined to drive the device. First of all, the operator needs to manually rotate the control box (not shown) to a certain angle and then drive the gear set and the spindle nut through the motor to reach the ultimate desired angle. In order to make sure that the nut does not rotate, you can go straight up, the guide rod mechanism installed. The structure is shown in Figure 1.

![Figure 1. The overall scheme of launching mechanism](image)

1- Launch rack tail support 2- shaft of the rear of the launcher 3- Launch rack tail intermediate support 4- Launch rack floor 5- Fixed angle plate 6- Upper part of the joint 7- Cross shaft 8- Lower part of joint 9- Putter 10- control box

The key technology of the launching mechanism is the precision of the movement of the space bar mechanism, and its movement diagram of the structure is shown in Figure 2.

![Figure 2. Movement diagram of launching mechanism](image)
In summary, the launching mechanism consists of a fixed platform 9, two sport branches and moving platform. Depending on the actual situation of the design, the launching mechanism has a degree of freedom and an initial condition, and finally needs to get the movable platform, that is, the launch pad floor elevation and left and right declination. The motion parameters of each part are given in Table 1.

### Table 1. The range of movement of each joint

| Components | Movement direction | Movement range       |
|------------|--------------------|----------------------|
| 1          | Around the Z axis  | -90°~90°              |
| 2, 3, 4    | Around the X/Y axis| 0°~20°, -15°~15°     |
| 5          | Around the Y1 axis | -90°~90°              |
| 6          | Linear motion      | 0~100mm               |
| 7          | Around the axis parallel to the Y axis | -90°~90° |

3. Analysis and simulation of launching mechanism

3.1. Establish dynamic model with gap transmitting mechanism

Before researching the dynamic model of launch mechanism with gap, the dynamic analysis of the model without gap in theory is first carried out:

For component 1 subjected to force analysis, component 1’s movement is relatively simple, only one rotation, there is no direction of movement. So the balance equation is:

$$J_1\ddot{\theta}_1 = F_{21}\ell_1$$  

Where $L_1$ is the force arm of member $F_{21}$ with force $F_{21}$.

Part 2 and moving platform 3 for analysis, because the quality of member 4 can be neglected, so the balance equation can be obtained as follows:

$$(J_2 + J_3 + J)\ddot{\theta}_2 = F_{32}\sqrt{L_2^2 + L_3^2} - \frac{1}{2}G_1\ell_1\sin\theta_2 - \frac{1}{2}(G_1 + G)\ell_3\sin\theta_3$$

Where $\theta_2$ and $\theta_3$ are the angles at which the member 2 rotates about the $x$-axis and the $y$-axis, respectively, and also the movement of the member 3 about the $x$-axis and the $z$-axis.

The component 5 is analysed. Since the component 5 and the component 6 are solid and the component 6 is the active component, the equilibrium equation of the component can be obtained as follows:

$$m_{65x}a_{5x} = F_{6x} - F_{5x}$$

$$m_{65y}a_{5y} = F_{6y} - F_{5y}$$

$$m_{65z}a_{5z} = F_{6z} - F_{5z}$$  

Since the rod 5 is fixedly connected with the driving part 6, the driving part 6 only has the moving movement.

Then, the kinematic secondary clearance is introduced into the above dynamic model, and the mathematical model of the gap adopts the contact force model. Among many contact force models, the Lankarani-Nikravesh contact force model[17] is selected and the mathematical model of the normal collision force is:

$$F_n = K\delta^* + D\dot{\delta}$$  

In addition, in the process of contact and collision, there are also tangential frictions between the moving vice, the mathematical model is:

$$F_t = \mu(v_t)F_n$$  

Then the rotation of the sub-rotation contact force can be expressed as:

$$F_c = u(\delta)(F_n + F_t)$$

So the kinetic equation, considering the gap when the mechanism of the kinetic equation can be got:
3.2. Dynamics Analysis of Launching Mechanism Based on ADAMS

Through ADAMS, the launching mechanism was simulated dynamics, and the influence of the moving clearance on the moving platform of the transmitting mechanism was analyzed. The launching mechanism model is simplified, and the model of space parallel link mechanism is set up. The theoretical launching mechanism and the gap transmitting mechanism are simulated under the initial conditions and initial force respectively. The dynamics model of launching mechanism is shown in Figure 3.

\[
\begin{align*}
\ddot{\phi} + C \dot{\phi} + K \phi + \phi'_{\lambda} \lambda &= F + F_c \\
\phi(q, t) &= 0
\end{align*}
\]  

(7)

4. Simulation Results

The result of the transmitting mechanism needs to be the position of the moving platform. Therefore, taking the opposite vertex of the moving platform as a reference point, the influence of the motion gap on the transmitting mechanism is analyzed through the change of the position of the reference point. At the same time, with the help of the velocity curve of the point to assist the analysis, the displacement and velocity curves of the apex of the moving mechanism of the transmitting mechanism according to the order shown in Table 2 are shown in Figures 4 to 7.
The above is the displacement mechanism and the speed curve of the moving platform when there is a gap between the transmitting mechanism and only one rotating auxiliary. In fact, since there is a gap in all the sports deputy, and the size of the gap will also be increased to varying degrees due to the different degrees of exercise, because the result is very complicated, the extensive studies will be conducted.

5. Analysis and discussion of results

There is a significant influence on the movement of the mechanism due to the secondary clearance in the launching mechanism. As can be seen from Figures 4 to 7, the irregularity of the main movement of the moving platform of the launching mechanism mainly occurs at the beginning of the movement.

The most important requirement for launching mechanism is the position requirement of launcher floor, which is, moving platform. Therefore, the movement parameter table of the absolute time of moving platform of statistical transmitter is shown in Table 3.

| parameters       | Displacement (m) | Speed (m/s) |
|------------------|------------------|-------------|
| No               | 0.069            | 0.1         |
| Tail support     | 0.0725           | 0.12        |
| Universal joints | 0.0615           | 0.1         |
| Fixed platform   | 0.066            | 0.11        |

As can be observed in Figures 4 to 7 and Table 3, the presence or absence of a gap has no effect on the form of motion. It only has a minor effect on the final location. There are two, namely the parts 1, 2 and 3 constitute a CR movement branch, the parts 6, 7, 8, 9 and 10 form another RRPU movement branch (where C is the rotation pair, R is the rotation pair and P is the movement vice, U for the universal joint). It can be seen that the motion of a branch with a universal joint is more complicated than that of
another branch, whereas the thumb branch with a large number of branches leads to an increased uncertainty of motion.

The impact of clearance on the launch mechanism is demonstrable. Moreover, the larger the clearance, the greater the influence on the transmitting mechanism will be. Therefore, it is necessary to reduce the clearance during the actual movement. Reducing the clearance reduces the relative movement of the clearance of the moving parts of the parts. Without changing the mode of movement of the launching mechanism, the launching mechanism can be modified as shown in Figure 8.

Comparing Figure 8 with Figure 1, it can be seen that in Figure 8, the axial contact length between the pin shaft and the shaft hole is enlarged, and the diameters of the pin shaft and the shaft hole are increased at the same time, which reduces the transmission mechanism around Hinge connection shaking, so you can better control the launch mechanism of the movement accuracy, reduce the movement error. At the same time, the use of thicker and thicker parts can increase the rigidity of the same structural part, so that the elastic deformation caused by the collision process is smaller and the movement accuracy of the launching mechanism is also improved. In addition, changes to the part material, the use of higher hardness materials for processing, can also reduce errors.

Figure 8. Launch mechanism’s improving device

6. Experimental research
For the study of launching mechanism movement, some experiments need to be carried out to verify the above calculation and simulation results. Portable missile launcher adjustment is shown in Figure 9.

Figure 9. Launcher device test chart

Due to the large range of movement of the launch mechanism, if a more detailed record of the data is required and the workload is very heavy, select a few specific values for testing and record as shown in Table 4.

| x(°) | y(°) | θ(°)  | L Theoretical value (mm) | L Measurements (mm) |
|------|------|------|--------------------------|---------------------|
| 0    | 0    | 0    | 8                        | 8                   |
| 5    | 0    | 31.16| 11.42                    | 11.6                |
| 10   | 0    | 47.66| 18.87                    | 18.8                |
| 15   | 0    | 56.97| 26.75                    | 26.92               |
| 0    | 10   | 0    | 40.95                    | 40.88               |
| 5    | 10   | 14.41| 42.81                    | 42.94               |
| 10   | 10   | 26.8 | 47.76                    | 47.9                |
| 15   | 10   | 36.63| 54.56                    | 54.72               |
The obtained data are compared with the theoretically calculated data to get the grouping error as shown in Table 5.

Table 5. Launch mechanism motion error table

| $y_{(°)}$ | 0     | 5     | 10    | 15    | 20    |
|-----------|-------|-------|-------|-------|-------|
| Error(mm) | 0.0725| 0.0725| 0.09  | 0.1   | 0.0625|

It can be seen that there is a definite gap between the actual launch mechanism motion and the theoretical value, but the error is relatively small. However, the test was performed just after the unit was completed and did not consider the effect of wear. If we adopt the improvement mechanism, the error will be further reduced.

7. Conclusion
Dynamic analysis of the launch mechanism, the space lever mechanism in the process of processing and use of the inevitable gap, and the impact of the gap on the launch mechanism was uncertain, so we considered the existence of the gap when the launch of the movement mechanism was necessary. First of all, a definite kinetic calculation of the launching mechanism model was carried out, and the contact force brought by the gap was adopted in the process. Based on ADAMS, the dynamics of launching mechanism were analyzed, and the launching mechanism under the influence of the gap was improved. Finally, the previous calculation and simulation were verified through experiments.

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