Structural Design and Dynamics Simulation Analysis of A Certain Type of Co-frame Launcher

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Abstract. To study the dynamic response of a certain type of co-frame launcher during launch, this article uses the 3D modeling software Pro/E to import the model into Adams from the perspective of launch dynamics. The launch dynamics model of the shared-frame launcher is established. We apply the ejection thrust of the two types of missiles to the corresponding ejection devices and measure and collect the dynamic parameters of the cartridge system. The simulation results show that the dynamic parameters of the A and B missiles are in line with the available overload design requirements. The B-type missiles are superior to the A-type missiles in terms of ballistic orbit contact force and ejection attitude.

1. Introduction

The co-frame launch technology was proposed in the 1970s to solve the background of the large variety of shipborne weapons and the small space of the combat platform. A variety of co-frame launch systems such as the MK series, Silva, and Skiley have appeared one after another [1]. According to its structure, the co-frame launch system can be divided into two types: multi-model multi-assembly (multiple bombs in one frame) and single-model multi-assembly (time-sharing launch) [2-3]. In order to achieve the purpose of air defense and anti-missile integration, the surface-to-air missile co-launching system mostly adopts a multi-projectile structure, and the typical representative is the Russian-made C-400 weapon system [4-5]. Yang Yanjie [6] analyzed the initial disturbance and stiffness characteristics of the projectile and rocket co-launch system from the perspective of structural design; Zhang Wenxiao [7] focused on the analysis of the influencing factors of the launch accuracy of the missile and rocket co-launch system on the move; Zhao Ming et al. [8] comprehensively analyzed the necessity of the development of co-shelf launch technology, the overall realization ideas, and determined the main constituent factors; Wang Jianguo et al. [9] further formulated the technical standards for compatible launch control of multiple bomb types and achieved a technological breakthrough in the universal launch platform for multiple and multiple types of guided rockets. Based on the above analysis, this paper established a dynamic model of a certain type of co-frame launcher, focusing on the analysis and discussion of the missile dynamic parameters, the contact force of the missile orbit and the posture of the missile.

2. Dynamic model of a certain type of co-frame launcher

2.1 Transmitting device connection relationship

The connection relationship of the main components of the co-frame launcher is as follows:

Type A transport launch tube: Actuator and launcher, brake cone and actuator, bracket and piston rod
all use fixed pairs to limit their relative movement; The piston rod and the actuator cylinder add a moving pair and contact collision for restraint; The guide rail and the orienter, the missile and the bracket, and the launch tube and the guide rail adopt a contact and collision constraint mode; the brake cone and the bracket are equivalent to damping springs.

Type B transport launch tube: Inside the launch tube, the brake cone is constrained at the mouth of the tube by a fixed pair; the missile, the tray, and the guide rail are restrained by contact and collision; The pallet and the brake cone are equivalent to a damping spring; the missile pallet and the launch tube are restrained by the moving pair and contact collision; On the outside of the barrel, a fixed pair is used to restrain the launch barrel and the pallet.

Hull and landing gear: The landing gear is connected to the body of the launcher through the trunnion device and the lifting hydraulic cylinder, A moving pair and a spring damper are used between the piston and the cylinder of the lifting hydraulic cylinder to simulate the relative movement between the two.

2.2 Kinetic model establishment
Taking the geometric center point of the lowest point of the base of the 4 transport launching cylinders (the base of the pallet) as the coordinate origin 0, The forward direction of the launch vehicle is the positive direction of the X axis, the ejection direction of the missile is the positive direction of the Y axis, and the positive direction of the Z axis is determined according to the right-hand screw rule to establish a global coordinate system. The local coordinate systems of other parts are established in this way, and the coordinate origin is set at the center of mass of each part. The established dynamic model is shown in Figure 1:

![Figure 1 Dynamic simulation model of a certain type of co-frame launcher](image)

3. Model pre-processing

3.1 Model main parameter settings
In order to get closer to the real working state of the launching device, the relative movement of related parts is restricted in the form of creating contact force in ADAMS.

3.2 Flexible body modeling
The piston rod and brake cone of the ejection device are made flexible, and the rigid-flexible coupling model of the launching device is established. The piston rod is appropriately structured, and the middle long rod is selected to establish a flexible body model, and the redundant parts at both ends of the rod remain rigid body properties. The generated rigid-flexible coupling model is shown in Figure 2:
3.3 System-related forces

Ejection thrust: The ejection thrust is the power source for the ejection tube of the missile. The ejection thrust of the A missile comes from the pressure of the gas on the piston rod in the low pressure chamber of the gas generator; the ejection thrust of the B missile comes from the gas pair produced by the gunpowder accumulator. The pressure of the missile tray. Figure 3 is a schematic diagram of the ejection thrust of the two types of missiles.

The braking force of the ejection device: the brake cone is made flexible, and the VFORCE unit is created, and the braking force is applied in conjunction with the IMPACT contact and collision function.

4. Dynamic simulation analysis of co-frame launcher

The vertical launch process of the two types of missiles is simulated, the simulation time lasts 7 s, and the number of steps is 500. The first 3 s of the simulation process are the self-balancing stage of the launcher. No ejection thrust is applied. Starting from the 3 s, the ejection thrusts of the two missiles shown in Figure 3 are respectively applied to the corresponding ejection devices to control the dynamic parameters of the barrel system. Perform measurement acquisition.

4.1 Analysis of Dynamic Parameters of Missile

Analysis of dynamic parameters of Type A missile: Figure 4 shows the curve of acceleration of Type A missile over time

It can be seen from the figure that the missile reached the maximum value of 147.16 m/s² at 3.05 s, and then it showed a trend of slow first and then fast. The overall change trend was close to the ejection thrust curve. The acceleration of gravity was taken as 9.8 m/s². Calculate the ejection process of Type A missile. The maximum overload, the result is about 15 g, meets the design requirements of the missile's usable overload.

Analysis of B-type missile dynamic parameters: Figure 5 shows the curve of B-type missile acceleration with time
It can be seen from the figure that the missile reaches the maximum value of 131.34 m/s² at 3.05 s, and the subsequent change trend is similar to that of the A-type missile; the acceleration of gravity is also taken as 9.8 m/s², and the calculated maximum overload of the B-type missile is about 13.4 g, which meets the design requirements of the missile's available overload.

4.2 Analysis of missile exit posture
Taking the global coordinate system as a reference, the following definitions are made for the exit attitude of the missile: rotation around the X axis is the yaw angle, rotation around the Y axis is the roll angle, and rotation around the Z axis is the pitch angle, respectively for the 3 types of the two types of missiles. Comparative analysis of posture.

4.2.1 Yaw rate
Figure 6 and Figure 7 are the curves of the yaw rate of the A and B missiles over time.

![Figure 6 Yaw angular velocity curve of Type A missile](image)

![Figure 7 Yaw rate curve of Type B missile](image)

It can be seen from the figure that when the trajectory constraint is completely eliminated, the yaw rate of the two tends to stabilize, respectively -1.26 deg/s and -0.02 deg/s, which shows that the B missile is superior to the A missile in the yaw attitude.

4.2.2 Roll angular velocity
Figure 8 and Figure 9 are the curves of the roll angular velocity of the A and B missiles over time.

![Fig. 8 Rolling angular velocity curve of Type A missile](image)

![Figure 9 Rolling angular velocity curve of Type B missile](image)

As can be seen from the figure, in the first 3 s simulations, Type A missiles show oscillation-attenuation, while Type B missiles have almost no decay process. The main reason for the different trends in the angular velocity of the two missiles is that the missile bodies are symmetrical in the same group. The installed orienters have different distances. In the case of the same ballistic orbit gap, the allowable roll angle of the B-type missile is larger; After the missile is ejected out of the barrel, the roll angular velocity of the A and B missiles are 0 deg/s and -2.94 deg/s, respectively. Although the
instantaneous angular velocity of the A-type missile during the ejection process is about three times that of the B-type missile, its roll posture after exiting the barrel is significantly better than that of the B-type missile.

4.2.3 Pitch rate

Figure 10 and Figure 11 are the curves of the pitch velocity of the A and B missiles over time.

![Figure 10 A-type missile pitch angle velocity curve](image1)

![Figure 11 Curve of pitch rate of B-type missile](image2)

In the self-balancing simulation stage, the amplitude of the missile's pitch angular velocity is smaller than the yaw angular velocity, which is in line with the fact that the distance between the front and rear orienters of the missile is much larger than the distance between the same group of orientators; After the trajectory constraint disappears, the pitch velocity of the two missiles tends to be stable. Among them, the pitch velocity of the A and B missiles are 1.43 deg/s and -0.04 deg/s respectively; similar to the yaw attitude, the B missile is significantly better than the pitch attitude of Type A missiles.

5. Conclusion

The article carried out dynamic simulation experiments on the vertical ejection process of the two types of missiles and focused on the analysis and discussion of the missile dynamics parameters, the contact force of the missile orbit, and the attitude of the missile exiting the barrel. It is concluded that the B-type missile is better than the A-type missile in terms of ballistic orbit contact force and ejection attitude.

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