Simulation Analysis of the Characteristics of the Latch Spring of the Switch Latch Mechanism Based on Virtual Prototype

Zhounan Guo

The 713th Research Institute of China Shipbuilding Industry Corporation Zhengzhou, China

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Abstract: In this paper, the switch latch mechanism is the research object. The virtual prototype model of the mechanism is established by software ADAMS and ANSYS. The curve of the spring force of the latch spring in the switch latch mechanism is simulated and analyzed, aiming to provide data support for the optimal design of the latch spring. By comparing and analyzing the results of multi-rigid dynamics and rigid-flexible coupled dynamics, this paper has obtained the research focus of two dynamic analysis methods. The research show that the results of the rigid-flexible coupled dynamics simulation analysis are more in line with the actual working conditions, and have more practical reference value.

1. Introduction

The change of social demand and fierce market competition require high-quality, low-cost and diversified new products to respond quickly to the market. The modern model of innovative product trial production is the key to its support. The new model of innovative product trials includes virtual prototype trials and physical prototype trials. The virtual prototype technology has small data preparation and calculation workload, and the simulation time of the whole machine features is short. It can repeat the cycle in the experiment process. The combination part of the whole machine is easy to process, the analysis precision is high, and the calculation software is convenient. The study of virtual prototyping technology is of great significance to the development of scientific theory and the practical application of engineering [1, 2].

The switch latch mechanism is complex, involving various constraints, a large number of spring forces and collision problems. As a key mechanism in the launch system, its smooth operation has a decisive influence on the realization of the full gun performance index. During the unlatching process, the collision between the open latching cam and the open latching template will cause shock vibration to the entire mechanism and even the launching system. During the latching process, the collision between the bottom circle of the cartridge and the extractor will affect the entire transmission. In this harsh working environment, the latch spring can guarantee the timing of the switch latch, which directly affects the normal shooting of the launch system [3, 4].

In this paper, the virtual prototype technology is applied to study the motion law of the switch latch mechanism. Based on the software ADAMS and ANSYS, the virtual prototype of the mechanism is established [5, 6], and the spring force change characteristics of the latch spring during the motion are mainly studied.

2. Mathematical model building

2.1 Working Principle

The switch latch mechanism has the function of closing the latch to close the air and opening the latch to pull out the cartridge shell, depending on the drive shaft to transmit the collision energy. The reliability of the mechanism directly determines the quality and efficiency of the gun during the launch process, and has always been an important research field for artillery practitioners.

As the only component of the switch latch mechanism that acts as a buffer collision [7] and energy storage function, the latch spring can be divided into two stages according to the action mechanism: the first stage, the switch latch mechanism is unlatched during the rear seat, and the latch spring is compressed. In the second stage, the switch latch mechanism is latched during the return process, and the latch spring releases the energy-assisted latch.

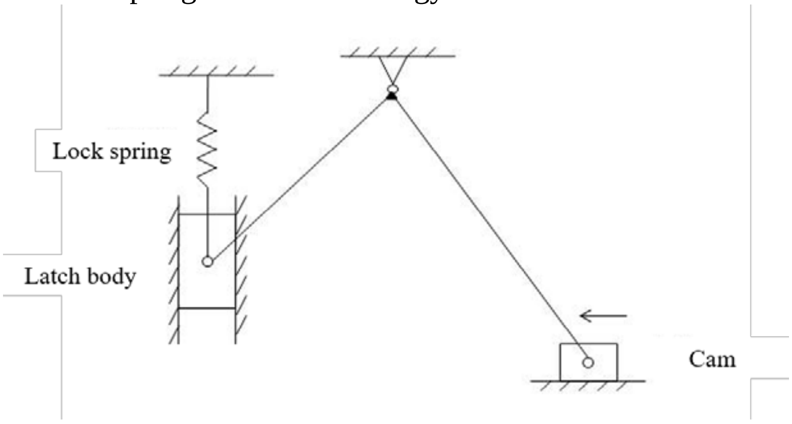


Figure 1. Switch latch mechanism physical model

As shown in Fig. 1, a large amount of collision energy during the operation of the switch latch mechanism provides the energy necessary for the mechanism to operate, and at the same time, a large amount of overshoot energy remains. In order to make full use of the residual energy and reduce the collision effect between the components of the mechanism, the latch spring stores most of the energy by the impact force into its own elastic potential energy and is released as effective energy during the latching process. This makes the study of the design parameters of the latch springs particularly important. This paper is also based on the simulation research and analysis of the important role of the latch spring.

2.2 Theoretical Basis

2.2.1 Spring dynamic equation

The latch spring of the switch latch mechanism belongs to a compression spring. Due to the vibration shock of the working environment of the spring, the deformation speed of the spring is large during the movement of the latch body, and the influence on the spring force is also significant, and the spring mechanical model is the effect of the spring's deformation speed on the spring force needs to be considered, so the mechanical model of the spring in ADAMS is [8]:

$$P=P_0- k(x-x0) -\zeta dx/dt \tag{1}$$

In the formula, P is the spring working force, P_0 is the spring preload, k is the spring stiffness, x is the spring working length, x_0 is the initial length of the spring, and ζ is the spring damping coefficient.

2.2.2 Contact collision equation

During the movement of the switch latch mechanism, many of the energy transfer is achieved by collision. The model of the ADAMS collision force is:

$$F = KL^{e} + \mu(L)\dot{L} \tag{2}$$

Where F is the normal contact force, K is the contact stiffness, L is the normal penetration distance of the contact point, μ is the damping factor, and e is the mechanical index of not less than 1.

In this paper, the impact function method is adopted for collision contact, and the contact stiffness coefficient is calculated by Hertz theory.

2.2.3 Empirical formula for shelling resistance

The shelling resistance is approximated by an empirical formula:

$$f = \mu F \pi (l-x)/l \tag{3}$$

In the formula, μ is the static friction coefficient, F is the residual deformation and pressing force of the cartridge, l is the length of the cartridge, and x is the length of the cartridge withdrawal.

3. Virtual prototype of the switch latch mechanism

3.1 Establishment of Virtual Prototype

In this paper, the three-dimensional geometric model of each part of the switch latch mechanism is established in the Creo environment, and in this environment, the assembly is performed according to the motion coordination relationship of each part. In order to increase the calculation speed, some parts that do not affect the movement process of the switch latch are simplified. Then the established 3D model is imported into ADAMS, and the model constraints are applied and simulated in this environment [9-11]. The ADAMS software simulation analysis steps are shown in Figure 2.

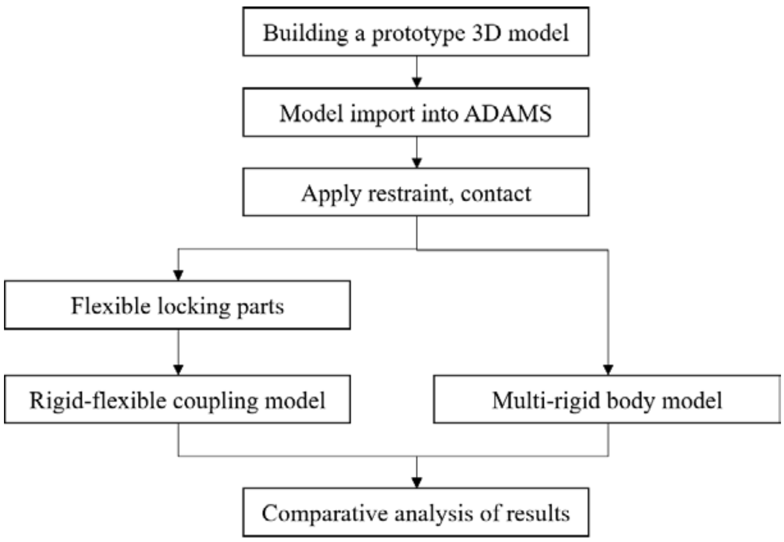


Figure 2. ADAMS software simulation analysis steps

3.2 Establishing a sports pair and collision contact

In order to improve the calculation speed and accuracy, under the premise of ensuring that the motion law of the mechanism conforms to the actual situation, the constraints between the model parts are replaced by line constraints as much as possible. The simplified model involves 20 rigid bodies, including 11 fixed pairs, 5 moving pairs, 2 rotating pairs, and 1 driving. The degree of freedom of the system is: 20×6-11×6-5×5-2×5. -1=18.

Energy transfer of the switch latch mechanism on the one hand through the above 18 constraints, on the other hand through collision between the components. In this paper, the collision contact is as far as possible using line contact, and the constraint is applied according to the contact collision equation (2).

The topological relationship between the cannon and each component is shown in Figure 3.

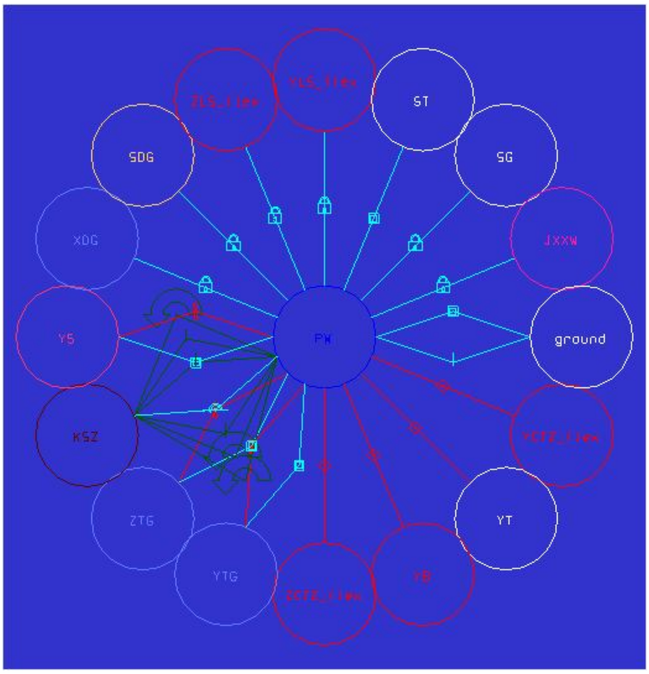
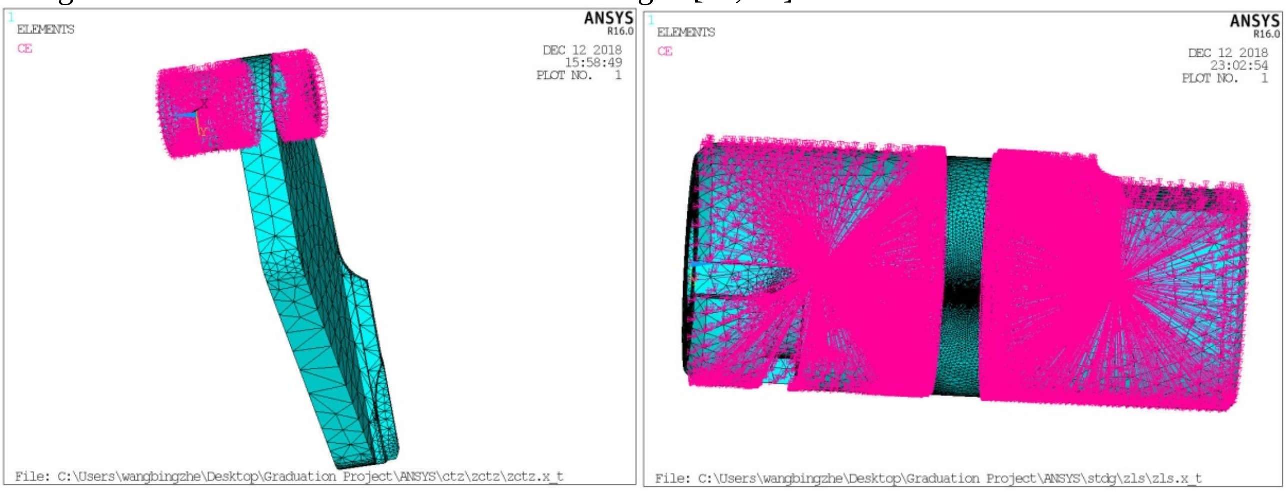


Figure 3. Topological relationship between the cannon and each component

3.3 Constructing a flexible body

Some parts are more flexible than other parts during the actual movement, and the slight deformation will seriously affect the dynamic response of the mechanism and the stress and strain of the part itself, thus affecting the judgment of the rationality of the mechanism design and motion. During the action of the mechanism, the deformation of the bar and the extractor affects the response speed of the mechanism and the curve of the spring force of the latch spring. In this paper, the response component is discretized into small mesh elements by the finite element software ANSYS. The generated finite element model is shown in Fig. 4 [12, 13].



(a) Finite element model of the extractor (b) Finite element model of bar

Figure 4. Finite element model of flexible component

Since the contact between the rigid bodies in the multi-rigid body model is no longer suitable for the constraint between the flexible body and the rigid body, the contact on the corresponding rigid body should first be removed before the rigid-flexible coupling simulation in the software ADAMS. After the rigid body is replaced by the corresponding flexible body, the rigid-flexible contact setting is performed by the rigid-flexible contact module in the software, and the rigid-flexible coupling model of the switch latch mechanism shown in FIG. 5.

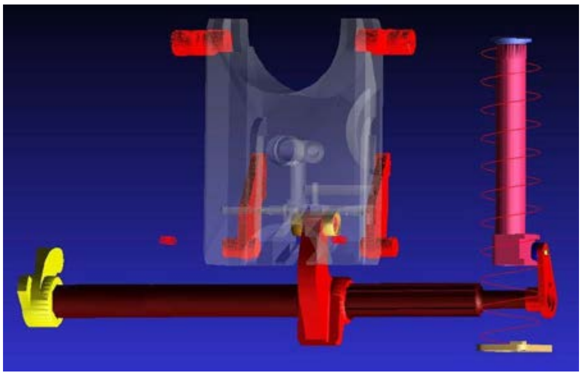


Figure 5. Rigid-flexible coupling model of switch latch mechanism

3.4 Applying load

3.4.1 Unlatching process

The main driving force is the return force provided by the recuperator during the unlatching process of the switch latch mechanism and the force of extracting cartridge case during the latching process of the switch latch mechanism. In order to control the variables in the simulation process, the return force and the force of extracting cartridge case are measured in the test are here.

3.4.2 Applying a return force

The return force in the recoil process of the launching system is the combined force of the recuperator and the recoil brake. The research is mainly to study the change of the spring force of the latch spring during the action of the switch latch mechanism. In the simulation process, in order to control the irrelevant variables and reduce the amount of calculation, the data of the return force measured during the typical test is imported into the ADAMS for curve call, and the obtained return force curve is shown in Fig. 6.

Figure 6. Reurn force curve

1) Applying the force of extracting cartridge case

The force of extracting cartridge case refers to the friction between the deformed cartridge and the inner tube of the cartridge under the action of the gunpowder force, which is mainly affected by factors such as the friction coefficient, the deformation of the cartridge, the length of the remaining cartridge, and the diameter of the cartridge. Here, the force of extracting cartridge case in the initial state is obtained according to the empirical formula equation (3), and is applied to the cartridge in the form of a one-way force, and finally the force of extracting cartridge case curve is obtained as shown in FIG.7.

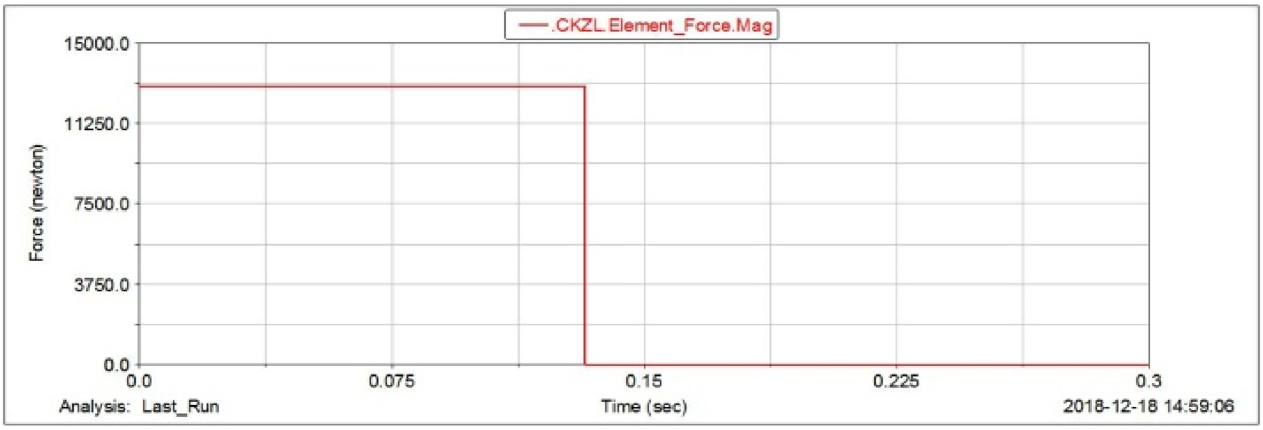


Figure 7. Force of extracting cartridge case curve

2) Latching process

The initial state of the switch latch mechanism is that the stern is stationary at a fixed position under the action of the cradle, and the switch latch mechanism is also in equilibrium under the action of the extractor and the latch spring. In order to control the number of variables in the simulation process, the spring speed measured in the test is applied to the transport cartridge, and the spring force of the push rod spring obtained during the design process is applied to the corresponding component of the mechanism as a known condition.

After the last shot, the switch latch mechanism is in the unlatched state, waiting for the input and exit of the cartridge in the next cycle and the subsequent latching action. Here, the cartridge moves out of the bomber and moves at a constant speed, and after the collision with the extractor, the switch latch mechanism is forced to latch until the latch is in place.

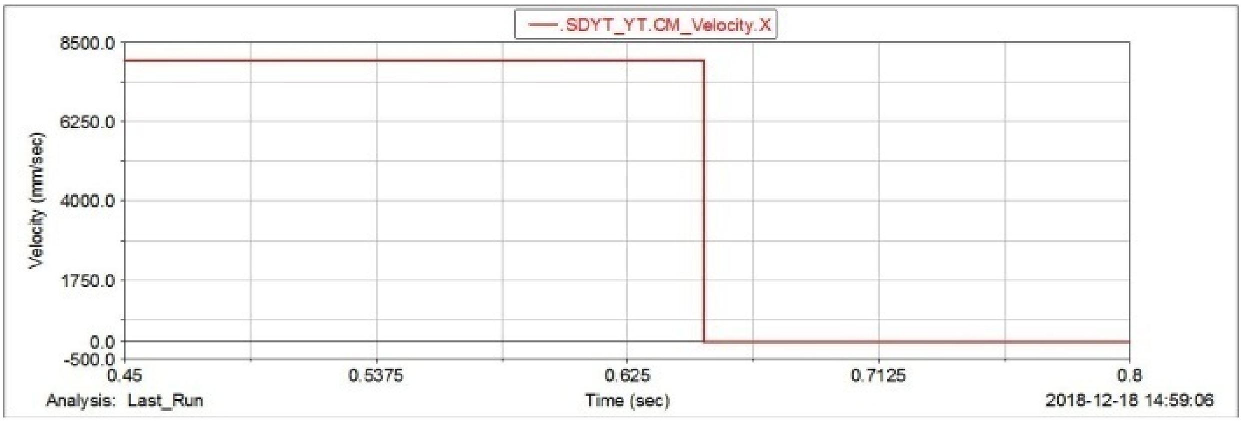


Figure 8. Cartridge transmission speed curve

The speed of the cartridge transmission during the research is the result of the combined action of the cartridge support and the air resistance. In order to reduce the influence of the unrelated factors on the simulation results, this paper directly uses the speed of the test cylinder to collide with the extractor as the cartridge transmission speed. The cartridge transmission speed is defined by the IF function, IF (DX (MARKER_271, MARKER_243) -7: 0, 0, -8000). The cartridge transmission speed curve is shown in Fig. 8.

4. Comparative analysis of simulation results

4.1 Multi-rigid system simulation results and analysis

According to the technical parameters of the latch spring force, the curve of the spring force of the latch spring compression energy and the spring force of the auxiliary latch phase are obtained through simulation analysis, as shown in Fig. 9.

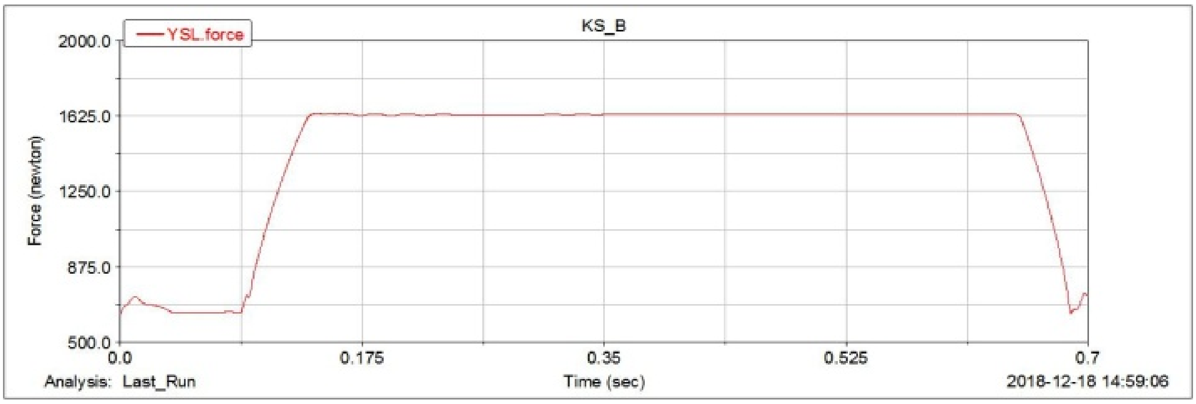


Figure 9. Latch spring force curve in multi-rigid system

It can be found from the curve shown in Fig. 9 that the spring force of the latch spring has a certain fluctuation at the position where the spring force is small during the unlatching process, because the spring force is insufficient to offset the fluctuation energy of the rotating shaft due to the rotation of the crank arm. The undulations appearing are caused by the rebound of the latching cam and the bolted template under the high-speed reentry motion during the unlatching process. The drum will hit the upper end cap under the rotation of the rotating shaft. The latch spring also has small fluctuations and eventually remains stable under the combined effects of latch weight, extractor support and latch spring force.

During the latching process, the latch spring force changes smoothly when the latch body is lowered. During the latching stabilization process, because the latch body and the latch body lever are in rigid contact, the latch body collides with the latch body lever and has a large rebound, and the spring force of the latch is small enough to balance the rebound force at this time, so with the bolt body will have large fluctuations and finally under the combined effect of the latching force and the spring force of the latch the latch spring force maintain stability.

4.2 Rigid-flexible coupling system simulation results and analysis

In order to study more deeply, the cam of the mechanism is flexibly processed to further analyze the variation law of the spring force of the latch spring during the action of the mechanism.

According to the technical parameters of the latch spring force, the curve of the spring force of the latch spring compression energy and the spring force of the auxiliary latch phase are obtained through simulation analysis, as shown in Fig. 10.

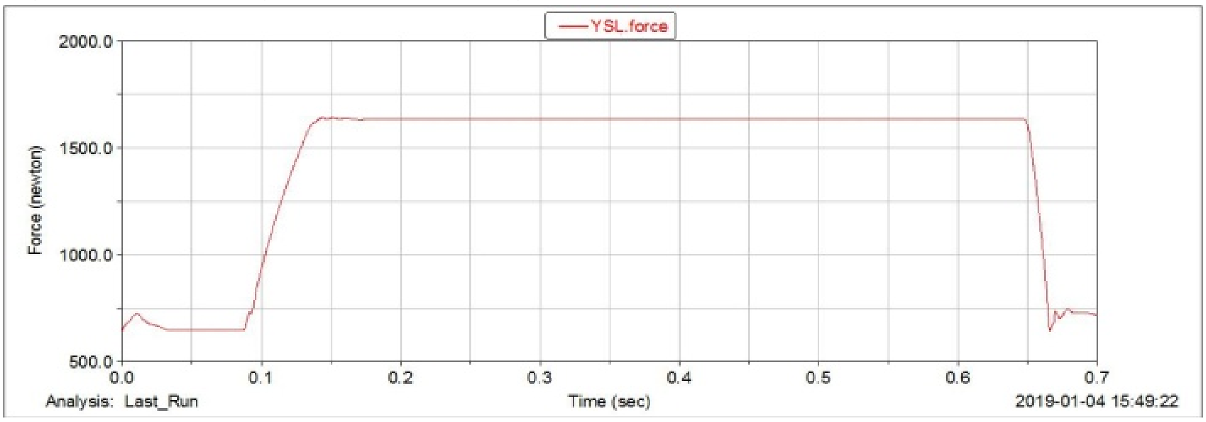


Figure 10. Latch spring force curve in rigid-flexible coupling system

It can be seen from the curves shown in Figs. 9 and 10 that the rigid-flexible coupling system and the multi-rigid system simulation have the same rule of the latch spring force variation curve. There is still fluctuation in the position where the spring force is small and the process of stabilization. But the spring force fluctuation during the unlatching process becomes small, the spring state is slightly maintained. The fluctuation in the process is mainly due to the fact that the damping between the two parts in the rigid-flex contact is much larger than the damping between the rigid bodies, so the collision repulsive force is reduced and the mechanism fluctuation becomes small. This change of the latch spring force curve fits the theoretical system of the rigid-flexible coupling system, and is a form of simulation optimization based on the simulation of the multi-rigid system, and is closer to the actual response.

5. Conclusion

Based on the software ANSYS and ADAMS, the multi-rigid model and the rigid-flexible coupling model of the switch latch mechanism are established. The simulation analysis of the mechanism is carried out according to the mechanism action of the switch latch mechanism. By comparing the latch spring force curves in the multi-rigid system and the rigid-flexible coupling system under typical shooting conditions, the influence of the flexing of key components on the change of the spring force of the latch spring is analyzed. The simulation comparison analysis results show that the rigid-flexible coupled dynamics analysis method is closer to the actual situation than the multi-rigid dynamic analysis method. It is feasible to analyze the change of the spring force of the switch latch mechanism through virtual prototyping technology. This method can effectively observe the spring force change of the latch spring in the test, provide data support for parameter optimization of the latch spring, and provide simulation research for similar structures.

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