Design of the New Locking Mechanism of Lock-iron Deflection Type and Dynamic Simulation

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Abstract: Rotary rigid locking mechanism It has the characteristics of reliable function, simple structure and it can shoot more powerful cartridge. Hence, it is universally utilized in the gun family which was developed independently by China. At present, the research level of rifle weapon locking mechanism structure has been significantly improved, but the research on dynamics simulation is still relatively few. To improve the research on the dynamics of the locking mechanism. Established the 3D model based on UG and selected locking block as the research object, established the dynamics differential equation of the locking mechanism through the dynamics analysis and make simulation on the model by using the ADAMS. The results show that the locking mechanism can be completed the unlock within 0.5 minute and lock within 1 minute, the motion characteristics of the recoil and reentry proved that the locking mechanism is coordinated, and the locking is reliable and went well. Dynamics differential equation of the locking mechanism of lock-iron deflection type provides a certain theoretical basis for the design of the automatic weapon locking mechanism.

1. Introduction
At present, the research level of small arms in China has been significantly improved, such as the 56-gun family. This gun family mostly utilize post-tensioning rigid locking mechanism, which manually complete a series of actions such as unlocking, ejection, feeding and locking. Rigid locking mechanism divided in three types contain rotary locking mechanism, deflected locking mechanism and Transverse locking mechanism [1]. this article proceeds dynamic research on rotary locking mechanism, providing certain theoretical basis and technological means for rotary locking mechanism. Thereinto transverse locking mechanism is not adopted to handle arm because its biggish locking mechanism size. Manual rifle’s mainstream bolt mostly utilizes rotary post-tensioning rigid locking mechanism [2]. Not only for its reliable function, but also can solve power issue through shooting powerful cartridge. At present, the research level of rifle weapon locking mechanism structure has
been significantly improved, but the research on dynamics simulation is still relatively few. To reduce constantly diagnostic test, bring from structure modifications of weapon demonstration phase, it can conduct theoretical simulation through system motion simulation. It can not only save material resources and manpower, but also shorten the development periodic. Basis on these arguments, this article establish the ejector-type rotary rigid locking mechanism motion model. The kinematics simulation analysis is carried out on this basis, which provides a certain theoretical basis and technical means for the research of rotary locking mechanism.

2. Rotary locking mechanism bolt model
Based on UG software [5], the locking mechanism utilizing rotary bolt of a rifle bolt was modeled. The shell mechanism is shell mode, and its three-dimensional model is shown in figure 1

Figure 1. Bolt components
1-locking mechanism 2- cartridge receiver and gun guide cartridge ejector 3-firing mechanism 4-extractor cartridge ejector firing mechanism extractor and other components composed of the cordial component—-bolt, conduct counter-recoil, locking, percussion, recoil, unlocking and other working cycles together.

2.1 Working principle analysis
While bolt pull cartridge into chamber, extractor block in the brim of cartridge. After chambering, the bolt finish rotary locking. And then the firing pin kick on centerfire, the cartridge pulls back under the impetus of gunpowder gas, the extractor block in the cartridge sheerly. After percussion, the bolt rotates and unlock. The air piston drives the bolt back, enable the extractor drives the case back. While the case back to the position of cartridge ejector, the cartridge ejector and the extractor form a couple to the case and then the case is rotated to the side and thrown. This cycle completes the recoil and ejection.

Figure 2. Schematic diagram of grasping force exerted on extractor.

2.2 Force analysis
Force analysis of extraction mechanism includes two parts: grasping force analysis and embracing, extracting force analysis [6] [7] [8].
Grasping force analysis

The brim of the shell case collides with the rake face of the teeth of the extractor after the bolt resets and pull the next cartridge into the chamber. On account of the inertia of the cartridge that creating tension $F_R$, the nearest distance from the axis of the extractor to the force $F_R$’s force line is b. $M_{R1} = F_R b$ is the moment enable ejector rotate towards outside. Regard $F_P$ as shell spring force, spring axis as direction. The minimum distance between ejector axis and $F_P$’s force line is a. $M_1 = F_P a$ is the moment block ejector rotate towards outside. In the procedure of the cartridge brim block in the ejector, the ejector interacts with the ejector’s axis. The support reaction of ejector's axis to ejector is $F_N$, which act on the contact, direction axis points to the axis. Conditions for outward rotation of the ejector: $W_R > W_P$.

![Figure 3. Extracting, embracing force analysis on ejector](image)

While the brim of cartridge conduct quitting, it generates the extracted resistance $F_Z$ affected by chamber and friction. The minimum linear distance from the ejector axis to the extracted resistance line is d. The shell case is subjected to the supporting force of the ejector when the ejector holds the shell case is F. The shortest linear distance from the axis of the ejector to the supporting force line is c. The ejector interacts with its shaft, and the supporting reaction force of the ejector is $F_N$, acting on the contact point, the direction axial is point to the axis. The extracted spring force is $F_P$, which action point is the contact point and the action direction are the spring axial direction. The vertical distance from the axis of the ejector to the force line of $F_P$ is a. Before the locking mechanism unlocks and quitting, extracted resistance force is $F_Z = 0$. At this point, according to the torqued balance of supporting counter-torque and the torque of the ejector's spring, so the shell holding force can be calculated: $F = \frac{F_P a}{c}$. After the rotary unlocking bolt, the bolt is driven back by the gas piston acting on the frame of bolt, to conducting extracting. The cartridge case began to rub against the chamber. The extracted resistance $F_Z$ is no longer 0. At this time, the holding force $F = \frac{F_Z d + F_P a}{c}$.

3. Establishment of mathematical model of dynamics

In order to facilitate the analysis, the dynamic model of rotary locking mechanism was established on the basis of ignoring some minor factors. The establishment of the model requires the following assumptions:

Consider that the components of the locking mechanism are regular and the centroid of each component is evenly distributed.

The rotary displacement of the ejector is small, ignoring the spring variable of the ejector, means $F_P a$ is constant.
Consider that the whole gun is kept level and not affected by the gravity component. According to the above hypothesis and the force analysis of the locking mechanism, according to Newton’s second law, the motion equation can be obtained as follows:

\[
\begin{align*}
\frac{m}{dt} &= F_z - F_p - F_{nx} \\
\frac{J_1}{dt^2} &= M_{R1} - M_1 \\
J_1 &= m_1 r^2 \\
M_1 &= FC \\
F &= \frac{F_z d + F_p a}{c}.
\end{align*}
\]

Where, \( m \) is the mass of shell case slider, \( m_1 \) is the mass of ejector, \( F_z \) is extracted resistance, \( F_p \) is extracted spring force, \( F_{nx} \) is the component of the supporting force along the elastic axis, \( J_1 \) is the Moment of inertia of ejector, \( M_1 \) is holding moment, \( M_{R1} \) is turning torque, \( r \) is ejector slider turning moment arm, \( \phi_1 \) is the angle of deflection, \( V \) is the translational velocity of the cartridge case.

4. Simulation

4.1 The simulation assumptions

ADAMS was used to simulate the dynamics of the bolt. In order to simplify the calculation, the following assumptions are made for the bolt:

1) The bolt is set to operate with the active parts and the offset of the bolt is ignored.
2) Reduce the fixed motion pair which is too complicated. For example, increase the size of the ejector port accordingly, or cancel the fixed connection between the gun and the ejector.

4.2 Adding constraints

The constraint in ADAMS/View defines the connection between the mechanisms and the relative motion mode. ADAMS/View has a relatively comprehensive constraint library. There are four main types:

Ideal constraints: rotating pair, moving pair, cylindrical pair, etc.;

Virtual constraint: constrains a certain direction of motion of a mechanism;

Motion generator: drive the member moves in a certain way;

Contact restriction: defines the way in which two components are restrained when they contact in motion.

Set motion pair: use fixed pair, moving pair, ball pair and so on respectively to add constraints on the device model. Use fixed pair constraints on fixed components that do not move with each other. In case of mutual motion between the components, a pair of moving pair constraints should be added to restrict the motion direction of the components. The ball pair is added to the ball connector and buffer components to ensure the relative movement of each other bolt constraint is as shown in figure 4.
4.3 Consequences of simulation.

Simulation was carried out according to the above assembly drawing, simulation time was set as 1s, the Step length was 1000, and the driving function was set as Step(time,0,0,5,90) + Step(time,0.5,0,1,-90). The default contact force of the system was added between components, the material of bolt is set as Steel. And the simulation of motion curve and cartridge case throwing route trajectory obtained as figure 5 and figure 6 respectively.

![Figure 4. Constraint addition graph](image_url)

**Figure 4.** Constraint addition graph

(a) : relation between velocity and time of the y-direction cartridge case
(b) : relation between velocity and time of the x-direction cartridge case.

From figure 4(a): speed of 0.5 seconds before the case within 0 ~ 5 mm/s floating. floating cause: among the early period of extraction, the bolt recoil and then the extraction is complete, the cartridge case displacement on the X direction should be 0. When simplifying the model, caused by a lack of constraints on cartridge case, leading to speed with small floating and the float value in the range of allowable error - 5 ~ 5 mm/s [9], will not affect the simulation. 0.5 ~ 0.75 second, the speed of ejector pulling back is stable, the cause which cartridge velocity floating within 0 ~ 15 mm/s is in order to ensure the ejector can operate rotary grasping easily, therefore, the design of the thickness of the ejector tooth of 0.75 mm should slightly less than the bottom of the shell slot width of 1 mm, so when the cartridge case turn to the right, the ejector appeared a certain displacement caused by cartridge case reaction, making the speed of the cartridge case appeared in small floating; After 0.75 second, the extractor supports the bottom edge of the cartridge case and the action of the ejector tooth to the
bottom edge slot of the cartridge case, forming a extracted couple, which causes the cartridge case to flip to the front right, then the cartridge case throw out of the window. At this time, the movement speed of the cartridge case is a primary function, and the extracted line is basically consistent with the actual situation.

5. Consequences
The following conclusions can be drawn through modeling dynamics research and ADAMS simulation of handpiece-rotary locking bolt:
1. It is proved that the rotating locking mechanism can reliably unlock in 0.5s and lock up in 1s.
2. The working route and movement relation of the basic components of rotary locking bolt effectively prove that the mechanism is reliable and the movement is concord. Besides, the extracted route is also accurate.
3. The kinematic simulation results show that the established dynamic mathematical model of the headpiece-rotary locking mechanism is correct, which provides a certain theoretical basis for the design of the locking mechanism and has certain guiding significance.

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