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Simulation Study on Technical State of Artillery Recoil Device

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Abstract. In order to keep abreast of the technical status of the recoil device, which is the key component of the artillery, it is necessary to monitor its technical parameters and judge its state according to the changing law of the technical state. Therefore, it is very important to accurately grasp the changing law of its technical state. In this paper, the recoil device is modeled by Amesim software and simulated by loading fault state, and the key parameters which can reflect the change law of technical state of recoil device are found out, which lays a foundation for realizing the comprehensive technical state monitoring of recoil device and mastering the change law of technical state of recoil device.

Keywords: Amesim software, recoil device, simulation, technical status

1 Preface

The recoil device of the artillery is the key component of the artillery, which controls the artillery to sit in place stably and safely according to the predetermined displacement and speed in the process of firing, so as to ensure the stability and stillness of the whole process of artillery action to the greatest extent. So as to improve the firing accuracy and ensure a certain firing speed [1]. As a key component of the artillery, the recoil device is in a harsh working environment of high pressure and transient during the firing process, and its internal components are affected by high-speed jet, friction, impact and so on. As a result, the recoil device has some faults, such as wear, liquid leakage, air leakage, disabled, poor fit, distortion and so on, thus affecting the function of the recoil device. When there is a fault in the recoil device, part of it is an external fault, which can be eliminated through appearance inspection and maintenance; the other part is a hidden fault, which is difficult to diagnose when the reverse recoil device is not decomposed or the fault state is not obvious. The technical status is difficult to determine. In order to realize the timely fault diagnosis of the recoil device, the technical status can be monitored during its working process, and the fault diagnosis can be realized by comparing the changing rules of the technical state. It can be seen that through the study of the change law of the technical state of the recoil device, it can lay a foundation for accurately determining the technical state of the recoil device. However, it is neither economical nor safe to study the change law of technical state through the firing process of live ammunition. Therefore, this paper simulates various working states of recoil device through Amesim dynamics simulation software, which lays a foundation for accurately grasping the change law of technical state of recoil device.

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2 Establish the Dynamic Simulation Model of Amesim

In the process of live firing, the artillery recoil device will produce complex fluid-solid coupling and gas-solid coupling impact vibration. In this paper, a certain type of artillery equipment is modeled by Amesim software [2], and the faults such as friction and wear of piston are simulated to study the influence of fault on the technical state of recoil device.

2.1 Amesim Dynamic Modeling

In a firing cycle, artillery mainly goes through two processes: recoil and re-entry. According to the force analysis of various parts in the firing process of the artillery, the dynamic simulation model is established by using Amesim software, which mainly includes the combined force of artillery bore, the retreating machine, the reentry machine and the speed regulating cylinder, as shown in Fig. 1.

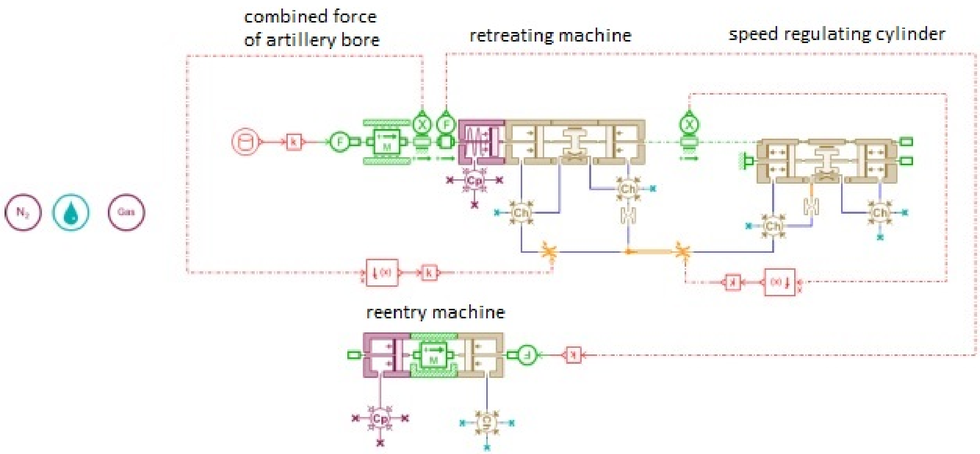

Fig. 1. Artillery dynamics simulation model based on Amesim

2.2 Amesim Simulation Parameter Settings

In the Amesim software, according to the structural characteristics of the recoil device and the needs of the research, the structure of the recoil device is subdivided, and the system is set to the simplest single sub-model (shown in Table 1). According to the divided sub-model and the technical size of the artillery recoil device, the initial amount of work will be set according to the corresponding parameter values.

Table 1. Artillery recoil device simplest sub-model list

Artillery recoil device			
parts	single sub-model	parts	single sub-model
Reentry machine	hydraulic chamber piston	Recoil machine	left end buffer spring chamber
	floating piston		non-working cavity piston
	gas storage cylinder		working cavity piston
	air chamber at the left end		non-working vacuum cavity
	the inner cylinder of the oil cavity at the right end		working hydraulic cavity
	the throttle hole between the inner cylinder and the outer cylinder		annular wedge-shaped clearance cavity cross-sectional area
	the outer cylinder oil chamber at the right end		annular wedge-shaped clearance cavity
speed regulating cylinder	regulating gap		buffer spring cavity
	piston at the right end of the speed regulating cylinder		clearance between the control rod and the control ring

3 Introduction of Fault Characteristic Parameters

The characteristic parameter [3] is defined as a parameter in various time and frequency fields. In the process of monitoring and diagnosis, the characteristic parameters which are less dependent on the operation state and less scattered diagnosis are usually used or introduced. Based on the characteristics of the structure and working environment of the recoil device, and combined with the engineering experience, the following characteristic parameters which can better reflect the fault characteristics are introduced:

(1) The average value, which describes the stable component of the signal, also known as the DC component, reflects the position of the equilibrium point of mechanical vibration;

(2) The mean square value and effective value are used to describe the energy of the vibration signal, It is used to judge whether the running state is normal or not;

(3) The peak and peak index refers to the single peak maximum of the vibration waveform. In the total length of a signal sample, the 10 numbers with the largest absolute value are found, and the arithmetic average of these 10 numbers is used as the peak value.

(4) Pulse index, is a statistical index used to detect whether there is impact in the signal;

(5) Margin index, margin index is used to detect the wear of equipment;

(6) Skew index, reflects the asymmetry of vibration signal, if there is friction or collision in a certain direction, the asymmetry of vibration wave will be caused, and the skew index will increase.

(7) Kurtosis index, kurtosis index reflects the impact characteristics of vibration signals.

4 Model Verification and Simulation of Injection Fault

4.1 Model Verification

Before injecting fault simulation into the model, the reliability of the simulation model is determined by verifying the change law of characteristic parameters during simulation and actual testing. The recoil stroke and recoil acceleration which can better reflect the technical status of the recoil device are introduced to verify the recoil stroke and recoil acceleration. By drawing the result diagram, the simulation curves of recoil stroke (Fig. 2) and recoil acceleration are obtained (Fig. 3).

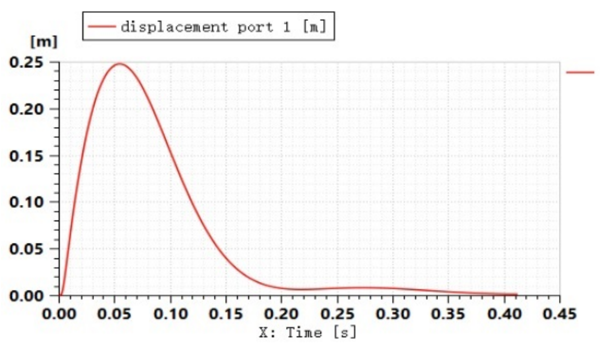

Fig. 2. Equipment recoil stroke-time simulation cureve

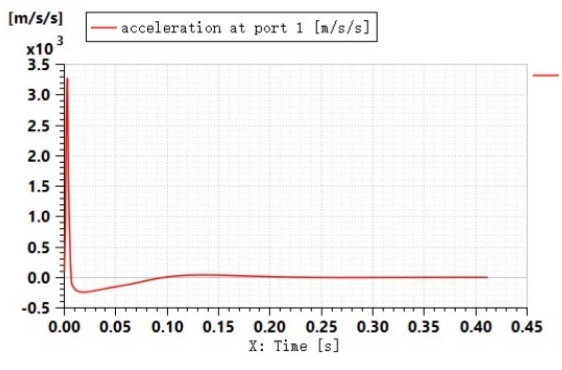

Fig. 3. Equipment recoil acceleration-time simulation curve

From the equipment simulation characteristic curve of Fig. 2 and Fig. 3, we can know the recoil characteristic quantity of the artillery model: the recoil stroke is 250mm, the maximum recoil speed is 9.4m/s, and the maximum recoil acceleration is 330g. The actual test result of the artillery recoil device is that the recoil stroke is 305 mm, the maximum acceleration is less than 308g and he maximum recoil speed is 9.1m/s. The comparison parameters are shown in Table 2, the relative error of stroke is 18.03%, and the error of maximum recoil speed is 3.29% and maximum recoil acceleration is 7.14%.

The simulation results of recoil characteristics are basically consistent with the actual test parameters of artillery, indicating that the Amesim simulation model is feasible and can be used to study the mechanism of equipment fault injection.

Table 2. Comparison of Amesim software simulation results and actual test results

	recoil and recoil stroke	maximum recoil speed	maximum recoil acceleration
Simulation results	250mm	9.40m/s	330g
Actual test results	305mm	9.10m/s	308g
Relative error	18.03%	3.29%	7.14%

4.2 Equipment Fault Injection Simulation

According to the investigation of the users and production units of the artillery recoil device, the friction and wear faults of the equipment include the friction and wear of the recoil machine and the friction and wear of the reentry machine. Among them, the wear faults of the retractor mainly include the wear of the control ring, the wear of the control rod, the wear of the piston sleeve and the control cylinder, the wear of the speed regulating cylinder of the control rod and the failure of the reentry controller. The wear faults of the reentry machine are mainly piston wear and piston rod wear [4]. This paper mainly simulates the wear fault of the reentry controller.

The reentry controller is mainly used to solve the problem of artillery reentry residual energy, and its main function is to produce resistance γ which can consume the reentry residual energy in the reentry process. In the process of reentry, the motion equation of the recoil part is [5]:

$$\frac{Q_0}{g}\cdot\frac{dV_f}{d_t}=p_f-R_f-\phi_f=\gamma \quad \textbf{(1)}$$

In the formula, Q_0 is the recoil part mass, V_f is the reentry speed, t is the reentry time, p_f is force of recuperator, R_f is the static resistance (the sum of the total friction force and gravity component $Q_0\sin\varphi$), ϕ_f is the hydraulic resistance produced by the reverse recoil device, $\gamma$is the reentry resultant force.

From the formula (1), it can be known that γ is directly or indirectly related to the parameters such as reentry speed V_f, reentry time t, reentry acceleration $a=\frac{dV_f}{d_t}$, reentry stroke $1=V_f*t$ and so on. as a result, it can be determined that the parameters of reentry stroke, reentry speed and reentry acceleration can be monitored in the process of simulation (as shown in Table 3), and the state change law of recoil device in the case of reentry controller failure can be better analyzed.

Table 3. Monitoring parameter table designed for simulation results of fault injection of reverse recoil device

Fault location	fault type	monitoring parameters			
		reverse recoil device mass			
		recoil stroke	reentry stroke	reentry speed	reentry acceleration
Reentry controller	wear	√	√	√	√

After determining the simulation monitoring parameters, combined with the introduced fault characteristic parameters for simulation calculation, the characteristic data in the case of equipment failure are obtained. The change law of the technical state characteristics of the recoil device under the wear fault of the reentry controller is shown from Fig. 4 to Fig. 11:

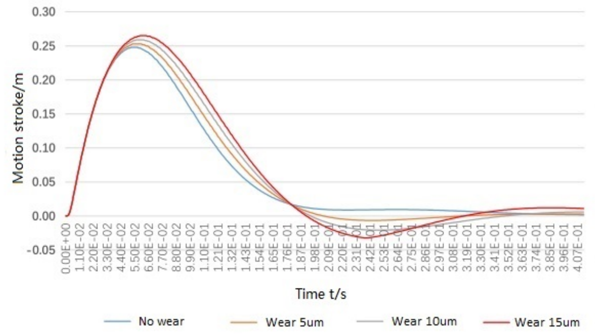

Fig. 4. Influence of the wear failure of the recoil controller on the recoil precession stroke

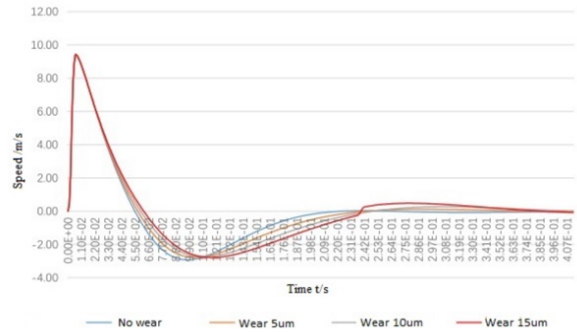

Fig. 5. Influence of the wear failure of the recoil controller on the recoil precession stroke

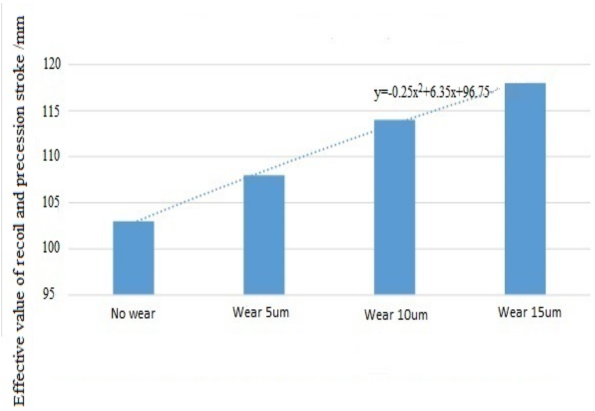

Fig. 6. Influence of the wear failure of the recoil controller on the recoil precession stroke

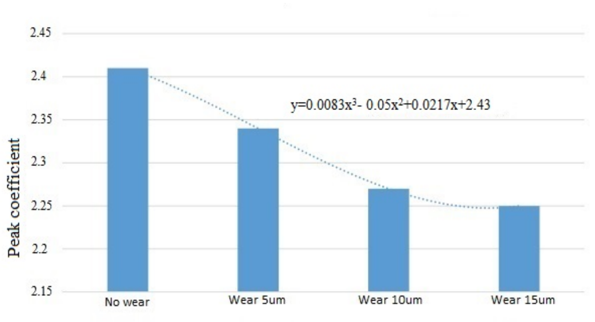

Fig. 7. Influence of recoil controller failure on recoil precession stroke peak coefficient

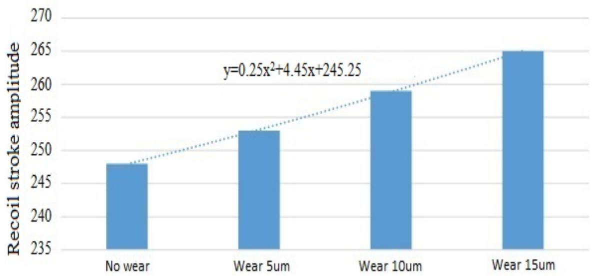

Fig. 8. Influence of recoil controller failure on recoil precession stroke amplitude

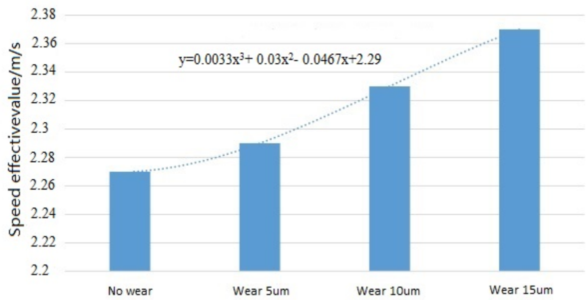

Fig. 9. Influence of recoil controller wear fault on recoil speed effective value

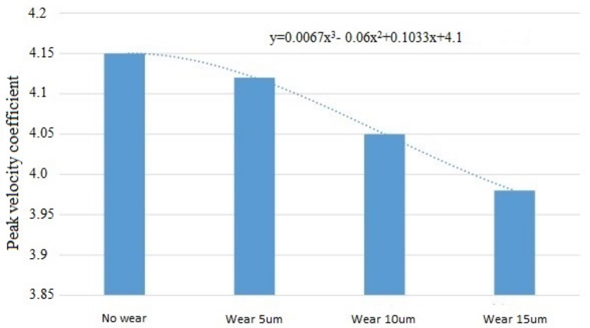

Fig. 10. Influence of wear failure of recoil controller on peak coefficient of recoil speed

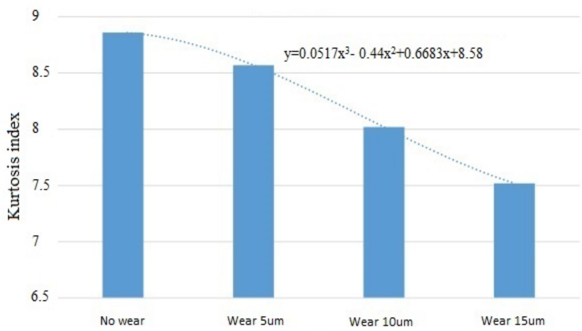

Fig. 11. Influence of wear failure of reentry controller on kurtosis index of recoil speed

4.3 Statistics and Analysis of Simulation Results of Fault Injection

According to the simulation results and simulation curves, the effective value of recoil stroke varies according to quadratic polynomial with the amount of wear (Fig. 6), and the peak coefficient of recoil stroke decreases according to cubic polynomial with the amount of wear (Fig. 7). The amplitude coefficient of the recoil stroke varies according to the quadratic polynomial with the wear (Fig. 8), and the effective value of the recoil speed varies with the wear according to the cubic polynomial curve (Fig. 9). The peak coefficient of reentry velocity decreases according to cubic polynomial curve with the amount of wear (Fig. 10), and the kurtosis coefficient of reentry velocity decreases according to cubic polynomial with the amount of wear (Fig. 11). Therefore, it can be made clear that the wear fault of the recoil controller leads to the change of the technical state of the recoil device [6]. Six kinds of fault diagnosis indexes such as recoil stroke amplitude, effective value, peak index, recoil speed effective value, peak index and kurtosis of recoil speed can better reflect the law of fault change by using recoil device recoil stroke amplitude, effective value, peak index, kurtosis and so on.

5 Summary

Based on the multi-body dynamics model of Amesim equipment and the simulation results, compared with the change law of the recoil device is known, it can prove the effectiveness of using Amesim software to simulate and study the fault mechanism of the recoil device. At the same time, combined with the fault analysis of the recoil device, the performance change law of the recoil device under the wear condition of the reentry controller is basically consistent with the analysis of the Amesim software. For the introduced characteristic parameters, six fault diagnosis indexes, such as recoil precession stroke amplitude, effective value, peak index, recoil speed effective value, peak index and kurtosis, can better reflect the performance change law of recoil device under the condition of reentry controller wear. In the process of analysis, because the analysis of the introduced parameters is still relatively simple, the influence intensity of the parameters cannot be compared, and the final determination of the monitoring parameters needs to be further determined, which needs to be further strengthened in the next step of simulation and calculation. In addition, the simulation analysis of solid-liquid coupling of recoil device needs to be compared with several softwares in order to find out the most suitable and reliable simulation method and ensure the accuracy of the research.

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