Failure Mechanism of Recoil Device of Tank Gun Based On Technical Test Platform

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Abstract. The recoil device of tank gun is the core component of artillery, and the fault source of tank gun recoil device often lies in the wear, ablation and poor sealing of internal devices, but these technical states are difficult to monitor. This paper studies the fault mechanism of tank gun recoil device based on technical test platform. In this paper, based on the factors such as transient action time of tank gun recoil device, various impact forces, complex test environment and great disturbance, a platform which can simulate the work of tank gun recoil device is designed. The fault parameters are obtained by sensor detection and simulation calculation, which lays a foundation for the study of the fault mechanism of the recoil device.

Keywords: Recoil Device, Technical Test, Platform Design, Fault Mechanism, Sensor Installation

1. Introduction

The main function of the recoil device of the gun is to consume the kinetic energy of the recoil of the gun, and to control the backseat within a certain range to ensure the normal operation of the gun. Its main structure is the retreat machine and the recoil machine. As the core component of the gun, the artillery recoil device not only affects the size and law of the gun force, but also affects the firing speed and accuracy of the gun. The real-time grasp of the technical status of the artillery recoil device can provide direct data support for the use, storage and maintenance of the gun, and provide a guarantee for maximizing the combat performance of the gun\cite{1}. At present, the research on artillery recoil device is mainly based on external detection\cite{2}, virtual prototyping\cite{3}, simulation technology\cite{4} and so on. At the same time, the calculation of parameters is mostly based on classical mechanics and empirical formulas, which has great limitations and errors\cite{5}. With the application of computer technology, but due to the transient action time of the anti-recoil device, various impact forces, complex test environment, great disturbance and other reasons, the research on the anti-recoil device still stays in the external and post-disposal aspects, and it is difficult to master the internal state of the anti-recoil device.

In order to study the phenomena of various fault states of the recoil device of a certain type of tank gun, the technical state test platform of the recoil device of tank gun is designed. The platform can...
realize the injection monitoring test of the typical technical state of the recoil device in the simulated high-intensity working environment, and real-time collect the changing characteristics of state signals such as pressure, recoil stroke and vibration, as well as the technical state-symptom relationship. And sort out the test data. In this study, the theoretical method and simulation method are used to study the technical state change and the main fault law of the equipment retreating machine and reentry machine, determine the fault change law, and establish the simulation model. Determine the change curve of the technical parameters about the influencing factors, and determine the parameters which are convenient for measurement and can correctly reflect the change of the technical state. Finally, the measurement parameters are analyzed and processed, and the mutual correspondence between parameter changes and various faults is completed, based on which the design scheme of fault diagnosis device is designed.

2. Platform Design

The failure mechanism platform of tank gun recoil device includes a tooling (adapted to the existing hydraulic recoil simulation platform and tank gun recoil device), pressure sensor and back-end data processing program for condition monitoring. Realize the working condition monitoring function of the recoil device, including simulating several technical states of the recoil device (wear, liquid leakage and air leakage) and the state drive of the recoil device. The main function of the platform is to simulate different high-intensity working conditions in the complex battlefield environment, and to monitor the state by using the vibration sensor, recoil stroke sensor and newly-built pressure sensor of the existing hydraulic recoil simulation platform. The signal is sampled in real time, and the test data are combed by the back-end data processing program, and several technical states of the anti-recoil device are reflected by the test data.

2.1 Scheme Design

2.1.1 Design of Technical Condition Test Platform. The technical state test platform of tank gun recoil device includes the tooling which adapts to the existing hydraulic recoil simulation platform and tank gun recoil device. It is required to design the interface which can connect the hydraulic recoil simulation platform and the 125mm gun recoil device, and design and install the interface of the existing hydraulic recoil simulation platform sensor. The structure of the platform is shown in the fig. 1.

The technical condition test bench of tank gun recoil device is 8000mm long, 1100mm wide and high 1550mm. It is composed of bench, simulated gun frame, simulated barrel, impulse generator, Fmurt controller, front buffer, rear pull cylinder, fastening assembly, rear slide seat, mass block and so on. The simulation gun frame is firmly connected with the test bench; the reentry machine, the front part of the retreat machine is firmly connected with the simulation gun frame, and the rear end is firmly connected with the simulated gun tail.

The failure mechanism of tank gun recoil device platform includes simulated gun tail and its connectors with retreat machine and reentry machine.

Figure 1. Test platform for technical status of recoil device
The simulated gun tail is connected with the simulated barrel, retreat machine and reentry machine. According to the design of 125mm tank gun tail, retreat machine and reentry machine, the mass and recoil stroke of the rear seat part are equivalent to those of the tested gun, and suitable for installation in the test platform at the same time [6].

When working, the rear pull cylinder is used to pull the impulse generator back to the waiting position, compress the gas in the impulse generator and store energy. The rear slide seat cooperates with the impulse generator and the guide rail, and the Fmurt controller body is connected with the pull rod and casing to guide the motion of the impulse generator. When the fastening assembly is released, the impulse generator moves forward and hits the simulated barrel to simulate the firing of the gun.

When the platform is working, the state signal of the recoil device collected by the sensor installed on the fault mechanism platform and enters the data acquisition system, and then the signal is transmitted to the computer (back-end data processing program) for signal processing and combing the data [7]. (shown in the fig. 2)

2.1.2 Design of Sensor Installation Interface for Fault Mechanism Platform. All kinds of sensor interfaces need to be designed on the fault mechanism platform, so that sensors can be installed to collect the real-time running state parameters of the recoil device of tank gun. According to the requirements of the experimental design, the sensors installed on the simulation platform are: steel wire tachometer (measuring range 0-1m, output voltage 0-5V, maximum allowable tensile speed 10m/s), three-axis accelerometer sensor (withstand temperature of 120℃), HM10-30 gas pressure sensor (measuring range 0-30MPa, output voltage 0-5V, response time 1ms), HM10-70 liquid pressure sensor (measuring range 0-70MPa, output voltage 0-5V, Response time 1ms), PT-1000 temperature sensor (measuring range 0~600℃).

Among them, the steel wire tachometer measures the displacement and velocity in the process of recoil and reentry, and is installed on the top of the simulated gun tail; the three-axis accelerometer measures the acceleration in the process of recoil and reentry, and is installed at the bottom of the simulated gun tail; the recoil stress plate measures the reverse recoil force of the recoil machine and the retreat machine in the process of recoil and reentry, which is respectively installed on the connecting rod of the recoil machine and the connecting rod of the retreat machine[8].

The gas and liquid in the cavity of the reentry machine and the retreat machine are measured by the pressure sensor; the temperature of the gas and liquid in the cavity is measured by the temperature sensor, and the pressure sensor and temperature sensor need to use the thread interface sensor. The test scheme is shown in fig. 3.
2.1.3 Software Solution. The platform analysis software uses Qt Creator development platform to complete, using C++ code editor to write code [9]. In the process of development, based on the data design technology and data management technology, the system constructs a closely related underlying data management platform for the state parameters of the tank gun recoil device, and realizes the classified recording of the test data in each state. On the basis of the above orderly management, the state parameters are quickly accessed through the visual interface. According to the actual demand, one or more state categories are selected to generate a visual curve analysis diagram for the relevant test measurement parameters, in order to realize the parameter analysis function. The specific functional framework mainly includes the management of test measurement parameters, the selection of test measurement parameters, the visualization of analysis results and other functions.

3. Test and Measurement Scheme
Based on the gun power recoil test-platform, the vibration, displacement and pressure signals of the recoil device are measured respectively. In the experiment, through the external force to simulate the action of gunpowder gas, push the recoil part of the gun to realize the simulated recoil and complete the recoil motion under the action of the recoil machine, and complete the recoil force and acceleration in the simulation recoil process. Recoil displacement and detection of air pressure and hydraulic pressure of the recoil machine. The thrust simulates the gunpowder gas force in the actual firing process, which is provided by the simulated recoil propulsion device of the hydraulic system and measured by the pressure sensor, the recoil displacement is measured by the steel wire tachometer, and the recoil acceleration is obtained from the corresponding displacement (taking the gun bore axis as the X axis, according to Newton's second law, the differential equation of recoil motion of gun equipment is established as follows:

\[
\frac{dx}{dt} = v, \quad \frac{dv}{dt} = \frac{1}{m_h}(F_p - F_p)
\]  

Among them: \(m_h\) is the recoil part mass, \(x\) is the recoil displacement, \(v\) is the recoil speed, \(t\) is the recoil time[5]). The air pressure of the reentry machine is measured by the pressure sensor installed on the reentry machine.

Under this measurement method, the test values under normal state and fault condition are tested in turn. The failure condition is realized by replacing the control rings with ad hoc faults in the simulation platform (0.1mm, 0.2mm, 0.3mm and 0.4mm).

Based on the gun power recoil test-platform, the vibration, displacement and pressure signals of the recoil device in five states are measured respectively. There were 3 tests in each state, 35 signal samples were collected each time, 105 signal samples were collected in each group, a total of 525 signal samples were collected, and the experimental report was formed.
5

4. Conclusion
In general, the hydraulic resistance caused by the gap between the control ring and the control rod plays a main role in the recoil process, and the wear of the control ring leads to the increase of the annular leakage area and the decrease of hydraulic resistance, thus increasing the recoil speed and lengthening the recoil distance [10]. It can be seen from (fig.4) that the recoil stroke increases with the increase of the wear of the control ring, and the reverse recoil force decreases with the increase of the wear of the control ring it can be seen from (fig. 7), which is more reasonable compared with the existing theory of the failure of the control ring. It shows that the measured data based on the technical test platform can better reflect the real state of the tank gun recoil device, and in the process of adding the control ring fault, it accords with the characteristics of the technical parameters of the anti-recoil device in the fault state. Therefore, it is considered that this method is effective in the research on the fault mechanism of anti-recoil device.

At the same time, because of the wear difference in the case of 0.1mm, the comparison of vibration acceleration, recoil and reentry speed, it is difficult to make a more obvious judgment, which is also the experimental design to be improved. On the basis of meeting the safety conditions, appropriately increase the test wear difference or increase the test shape, in order to better explore the working law of the recoil device. In addition, due to the limitations of experimental conditions, the current fault setting is only limited to the control ring wear in the wear fault, the lower part will continue to explore the control rod wear, liquid leakage and air leakage and other aspects of research.

References
[1] Zhang Xiangyan, Zheng Jianguo, Yang Junrong. Artillery firing theory. Beijing Institute of Technology Press, 2005.2
[2] Zhou Shihai, Fan Pengfei, Yang Yuying. Study on an automatic temperature measurement technology of reverse recoil device and its control method. Computer measurement and control. 2017.25(5)
[3] Zhang Jingbo, Cheng Li, Hu Huibin, Cao Lijun. Research on fault simulation technology of recoil device based on virtual prototype. Computer Measurement and Control,2012.05(03)
[4] Xu Xinqi, Han Xiaoming, Li Qiang, Liang Xingwang. Structural simulation analysis of recoil
device based on AMESim and Simulink. Hydraulic and pneumatic. 2019.04.016
[5] Gao Shuzi, Chen Yunsheng, Zhang Yuelin. Gun recoil device design. Beijing: national Defense Industry Press, 1995 -57-62.
[6] Hou Shenggao, Liu Xueyin. Tank weapon system structure and use. Interior, 2019.09-1
[7] Sun Deren, etc. Weapon dynamic parameter testing technology. Beijing: Beijing Institute of Technology Press, 2013.1
[8] Conghua, Fan Xinhai, Qiu Mianhao, etc. Armored vehicle testing. Beijing: Beijing Institute of Technology Press, 2019.6
[9] (Canada) Jamin Blanchette, (English) Mark Summerfield. C++GUI QT4 programming. Electronic Industry Publishing Press, 2018 :01-01
[10] Sun Ye-Zun, Qin Junqi, Di Changchun. Research on Fault Law of Brake and retreat Machine based on Collaborative Simulation Technology. Firepower and Command and Control, 2014