Research on a fault test system based on fault injection

Yang Cao, Hongtian Liu, Chao Song, Yizhuo Jia, Liu Yao, Jianwei Zhang, Dongjun Wang
Department of Weapons and Control, Army Armored Forces Academy Beijing, China
190233004@qq.com

Abstract—Fault injection technology is an important method in system fault testability. By monitoring and analyzing the response information of the system after fault injection, the evaluation results of the reliability and fault tolerance characteristics of the target system can be obtained, which can provide data reference for equipment maintenance support. In this paper, aiming at the problems of complex composition, difficult fault detection and isolation, and low efficiency of maintenance training of armored equipment weapon system, a fault testing system based on fault injection is established by analyzing fault mechanism and designing fault injection scheme, which provides reliable technical support and technical support for operators to conduct fault analysis and maintenance training effective methods and means.

1. Introduction
With the increasing complexity of weapon equipment, the difficulty of maintenance support is also increasing. Maintenance support ability has become an important index to measure the performance of equipment. Testability is a kind of design characteristic that the system and equipment can determine its working state timely and accurately and isolate its internal faults. As an attribute of monitoring system, it can improve the reliability and reliability of monitoring system and improve the reliability and reliability of the system.

Fault injection refers to the test process that according to the selected fault model, the fault is consciously generated by manual method and applied to the tested object with specific load. Meanwhile, the success or failure results of fault detection and isolation of test and diagnosis system are observed and collected, and the collected data of detection and isolation success and failure are statistically analyzed, so as to provide relevant results to users [1][2].

Fault injection technology is an important method in system fault testability. By monitoring and analyzing the response information of the system after fault injection, the evaluation results of the reliability and fault tolerance characteristics of the target system can be obtained, which can provide data reference for equipment maintenance support. Aiming at the problems of complex composition, difficult fault detection and isolation, and low efficiency of maintenance and training of armored equipment weapon system, a fault testing system based on fault injection is established through fault mechanism analysis and fault injection scheme design of an automatic loader. The system can conduct fault injection according to the setting, and guide the operator to carry out fault analysis and maintenance training provides reliable technical support and effective methods [3].

2. Failure analysis of autoloader components
A certain type of automatic loader is a kind of Mechatronics integrated system, which is suitable for fixed angle automatic loading of large caliber guns, sub loaded ammunition and various kinds of
ammunition. It is mainly composed of gun locking device, rotary ammunition conveyor, lifting mechanism, projectile pusher, shell throwing mechanism, program control box and other components. In this paper, the failure phenomenon and mechanism of gun locking device are analyzed. The function of the gun locking device is to lock the gun at a specific loading angle position during automatic loading, and unlock the gun after loading.

2.1. Analysis of control signal transmission process

2.1.1. The gun is locked at the loading angle
When the gun has just entered the loading angle area, the program control box outputs the locking signal of the gun locking device, and the gun locking motor rotates forward. When the gun locking device is locked in place and outputs the locking in place signal to the program control box, the control signal output by the program control box changes from high level to low level, the gun locking motor stops working, and the gun is in the locking state. The signal transmission relationship between the gun locking device and the program control box is shown in Figure 1.

Figure 1 Signal transmission relationship between gun locking device and program control box

2.1.2. The gun is released from locking and returns to its original position
When the shell throwing mechanism frame is lowered to its original position, the program control box outputs the recovery signal of the gun lock, the motor of the gun lock reverses, the closed lock pin is retracted, and the gun lock is released. When the locking pin is retracted, the lock out signal of the gun lock is released to the program control box. The control signal output from the program control box changes from high level to low level, and the gun lock motor stops working. The signal transmission relationship between the program control box and the gun lock is shown in Figure 2.

Figure 2 Signal transmission relationship between program control box and gun locking device

2.2. Analysis of fault mechanism
Through a large number of data statistics and analysis, the common failures of gun locking device are as follows:

1) In automatic mode, the gun locking device is not locked;
2) In automatic mode, the gun locking device does not lift the frame after locking.

According to the above signal transmission process, under normal conditions, after the gun locking device is locked in place, it outputs the locking in place signal to the program control box, and the program control box outputs the frame lifting signal to make the shell throwing mechanism motor rotate forward and lift the frame. It can be seen from this that if the gun locking device fails, the possible causes are as follows:

1) The program control box itself fails to receive the locking in place signal or it does not output the frame lifting signal;
2) The frame of the shell throwing mechanism is stuck or the motor fails, so it is unable to lift the frame;
3) The failure of microswitch of gun locking device results in no output of locking position signal to program control box after locking in place;
4) The failure of the gun locking motor results in the failure of the gun locking device;
5) The signal can’t be transmitted due to cable failure.

The fault tree of gun locking device is shown in Figure 3.

Figure 3 fault tree of gun locking device

The mechanism analysis of typical fault phenomena of other components is the same as above, and will not be detailed in this paper.

3. Fault injection scheme

3.1. The design idea of this system

The typical faults of autoloaders are often manifested in the dislocation and failure of microswitches of these executive parts, and the blocking of parts leads to poor movement. Therefore, fault simulation and injection need to start from these aspects, by simulating the failure of switch, abnormal motor or electromagnet action, and sending fault injection signal to the autoloader system, truly reflecting the failure phenomenon of the automatic loader when the corresponding fault occurs.

The actuators of the automatic loader mainly respond to and execute each action program under the action of the driving signal output from the program control box, and the program control box outputs the corresponding driving signal according to a certain program after collecting the relevant state information of each actuator to control the transmission of all kinds of signals. Therefore, by adding a fault injector with hardware structure between the actuator and the program control box of the automatic loader, the relevant signals of the automatic loader system can be controlled according to certain fault injection logic and control program, and then the predetermined fault injection can be realized. The so-called fault injector is to make the fault injection method into a corresponding tool for fault simulation and injection.

For example, for the failure of gun locking device, it can be seen from the above failure mechanism analysis that the failure of program control box, shell throwing mechanism, locking device body and cable fault can lead to the occurrence of gun locking device failure. In fact, the fault of the program control box interrupts the normal transmission of the locking in place signal output by the gun locking device; the shell throwing mechanism fault interrupts the normal transmission of the frame lifting signal output from the program control box; the normal transmission of the output signal of the micro switch or the locking device motor is interrupted by the fault of the locking device body; the normal transmission of these signals is also interrupted by the cable fault.

3.2. Working principle of the system

The normal/fault signal should be stroked in the connection part of microswitch of each actuator, and the corresponding fault injection channel should be established in the fault injector. The fault injector
sends the fault injection signal to the automatic loader system by selecting the corresponding fault injection point, so as to carry out the fault simulation and injection. The whole fault injection system uses high reliability isolation technology through the relay cable to realize seamless access to the autoloader\textsuperscript{[4]}. Its working principle is as follows:

Firstly, the fault injector collects the status signals output by the actuators of the automatic loader, that is, the input signals of the fault injector; secondly, the fault injector can simulate these state signals and input them to the program control box of the automatic loader according to the corresponding control commands, and at the same time, it can also simulate the drive signals output by the program control box and input them to the automatic loading machine according to the corresponding control commands. The output signal of the fault injector is the output signal of the actuator. The fault injection management software is installed in the system terminal, which can monitor and display the status signals collected by the fault injector in real time. According to the fault simulation and injection strategy, the corresponding control commands are sent to the fault injector through the communication bus, and then different signals are output to the actuators or program control boxes of the automatic loader by controlling the fault injector, so as to realize the fault simulation and fault diagnosis injection. When a fault is injected, the management software can automatically call out the maintenance knowledge base to guide and train operators. The working principle of fault injection is shown in Figure 4.

![Figure 4 working principle of fault injection](image)

**4. Design of fault injection system for Autoloader**

**4.1. The hardware design of the system**

The hardware part of the automatic loader fault injection system is mainly fault injector, which is composed of signal input conditioning circuit, main control unit circuit, signal output control circuit, power supply circuit, communication circuit, etc. The system composition is shown in Figure 5.

![Figure 5 Composition of fault injection system](image)
to the command requirements, the main control unit of the fault injector outputs different state signals to the signal output control circuit according to the fault injection strategy.

Signal output control circuit for signal processing: first, through the simulation of various on-off signals output from the program control box, input to each actuator to realize the fault injection of the automatic loader; second, through simulating the various on-off signals output by each actuator of the automatic loader, input them to the program control box to realize the fault simulation of the automatic loader.

In the whole process, the fault injection management software of the system terminal can monitor various state signals and control various control signals in real time. When a fault of the automatic loader is simulated, the corresponding fault diagnosis content and maintenance strategy can be called out from the maintenance knowledge base to guide the operators to learn and train in maintenance.

4.2. Software design of the system

Fault injection management software is the control part of fault injection system. It is mainly composed of automatic loader status signal monitoring program, fault injection control program and maintenance knowledge base. Its main function is to drive system hardware, communicate with fault injector, provide interactive operation interface and complete fault setting, fault maintenance learning and training. The system software can be developed by using LabWindows/CVI interactive development platform, which has rich user interactive controls and various virtual instruments, and can establish complex virtual interface and realize complex interactive process.

The fault injection of autoloader is realized by man-machine interaction through the control operation of software interface. The software design flow is shown in Figure 6[5].

When the program starts to run, the first step is to check the communication connection with the fault injector and configure the corresponding communication port.

The second step is to initialize the hardware of the fault injector to ensure that the fault injector is compatible with the automatic loader.

The third step is to enter the main interface of the system for the user to select.

The fourth step, according to the user's choice, enter the corresponding function interface, mainly including monitoring the output signal of each actuator of the automatic loader, controlling the fault injector to output matching signal to the program control box, and providing maintenance training guidance for the trainer according to the injected fault[6].

The fault maintenance library is nested in the running software. After the fault injection is set, the corresponding fault maintenance content will be displayed in the fault information column, which is convenient for the operator to consult and provide decision for troubleshooting.
5. CONCLUSION
The automatic loader fault injection system designed in this paper, through the initialization of the fault injector hardware, and then real-time monitoring of the automatic loader actuator output status signal, and according to the signal state, through the output signal control circuit to the program control box. At this time, if fault injection is needed, the corresponding fault injection signal can be selected according to the fault injection assembly, and the state can be switched through the system software interface button.

Through some series of fault tests, it shows that the fault injection system can carry out fault injection and fault simulation according to the preset settings, and after fault injection, the maintenance contents of corresponding faults are displayed, which provides reliable technical support and effective methods for guiding operators to carry out fault analysis and troubleshooting and maintenance training.

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