A Design of Test Equipment on Gun Control Systems and Autoloaders

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Abstract. In response to a series of problems in the actual use of a certain type of tank fire control system and autoloader, such as many sudden failures, difficulties in diagnosing and locating failures, and complex maintenance and guarantee, a testing equipment is designed for the gun control box and autoloader, which is used to monitor the status of the gun control box and autoloader, and store the test data in real time. By comparing the test data and analysing the abnormal problems that occur in the work of the gun control box and the autoloader, it realises the monitoring of the working condition of the tank gun control box and the autoloader components, providing effective data support for the next step of repair.

1. Introduction
The weapon system of a certain type of tank is equipped with an advanced head mirror image-stabilized fire control system, which realizes the stable control of the gun and the fast tracking of the target when the tank is moving, and improves the autoloader of the tank, improving the loading speed of the ammunition and enhancing the fire mobility. It is a highly complex automatic special machinery integrating dynamic tracking, laser ranging, electro-hydraulic following and automatic ammunition selection, with complex structure, high accuracy requirements, high failure rate and great difficulty in maintenance.

According to the statistical failures of the weapon system parts of tanks equipped in different regions, the highest frequency of failure is found in the fire control system, followed by the electrical failure of the autoloader, and then the mechanical failure of the gun part. In general, it is difficult to directly diagnose the cause of the failure of the fire control system and the autoloader, which has a greater impact on the use of the equipment and requires the use of special fault detection equipment for detection and diagnosis.

In response to a series of problems in the actual use of tank fire control systems and autoloaders, such as many sudden failures, difficulties in fault diagnosis and positioning, and complex maintenance, it becomes urgent to develop fast and efficient information-based fault test equipment (hereinafter referred to as test equipment) to reduce the maintenance difficulty of weapon systems, improve maintenance efficiency and guarantee the normal conduct of firing training by studying the patterns and laws of fault occurrence and fault diagnosis techniques [1].
With the rapid development of detection technology, test equipment can conduct real-time monitoring and automatic diagnosis, which is the main development direction of work condition monitoring and fault diagnosis. In terms of the structure of the detection system, the centralised monitoring method is replaced by a distributed monitoring method, data acquisition and condition monitoring is achieved by an intelligent front-end device, and fault diagnosis is completed by a central computer, realising a distributed system structure and a hierarchical monitoring method. At present, great progress has been made in the fault detection of armoured equipment weapon systems, and some test equipment has been developed, but there are some general problems with these devices: they are unable to monitor and record system status parameters in real time; single-functional; cumbersome to use; not very accurate; not suitable for rapid fault detection in field conditions, etc. [2].

2. Functional requirements and composition of the test equipment

In view of the current realistic problems of fault detection equipment for armoured equipment weapon systems and some of the statistical faults, the functional requirements and composition of the test equipment are as follows.

2.1. Analysis of the functional requirements of test equipment

The test equipment is capable of monitoring the online working status of the tank gun control box, mainly monitoring the data output from the online testing interface of the gun control box; it is capable of monitoring the online working status of the tank autoloader components, mainly monitoring the data of the autoloader control box interface through the tee cable; it supports the export, backup and query of the test data and test results of the gun control box and autoloader.

2.2. Composition and functions of the test equipment

The test equipment includes the mainframe, test kit of the gun control box, the test adapter of the autoloader, the cable and the packaging box.

2.2.1. Composition and functions of the mainframe

The mainframe of the test equipment is used for data acquisition, data analysis, data solving, test result display and function control. It includes CPU module, multifunctional acquisition module, multifunctional carrier board, touch display, custom keys, panel connector and chassis.

The CPU module is mainly used for data analysis, data decomposition and other data processing. The CPU module sends control commands to the multi-functional acquisition module, which outputs I/O signals to the working control terminal of the relay on the conditioning board to make the relay operate and achieve the purpose of relay suction. It provides working power to the conditioning board, so that the whole test equipment can work normally.

After the test equipment starts working, the CPU module sends the acquisition command to the multi-functional acquisition module, which is output by the gun control box or the autoloader and goes through the detection cable to the detection kit of the gun control box or the detection adapter of the autoloader. The voltage value is made within the range that can be collected by the multi-functional acquisition module after the conditioning process such as isolation, reduction or amplification of the conditioning board. Then, the command is input to the multi-functional acquisition module through the resource cable, and transmitted to the CPU module. After data analysis and data decoding by the CPU module, it is finally transferred to the touch screen by the CPU module.

2.2.2. Composition and functions of the test kit of the gun control box

The main function of the detection kit of the gun control box is to condition and transfer the signals from the mainframe and the signals from the gun control box. The detection kit of the gun control box includes a first conditioning board and a first test kit housing. The main function of the first conditioning board is to condition the input and output signals, including isolation, amplification, reduction and other conditioning, so that the signal can be within the range of the mainframe’s
acquisition signal. At the same time, it can protect the host computer. When the acquisition signal is abnormal, it limits the abnormal signal at the input of the signal to a range that is safe for the mainframe to collect, so that the mainframe and the gun control’s detection kit are not irreversibly damaged. The first test kit housing includes a first upper cover, a first lower housing and a first panel connector, mainly for mounting the first conditioning board and mounting the first panel connector, and for protecting the first conditioning board. The first panel connector is used to connect the resource cable for the mainframe resource and the detection cable for the self-test port of the gun control box. The constituteframe of the conditioning board is shown in Figure 1.

![Diagram of the conditioning board](image)

Figure 1. The constituteframe of the conditioning board

### 2.2.3. Components and functions of the detection adapter for the autoloader

The main function of the detection adapter of the autoloader is to condition and transfer the signals from the mainframe and the signals from the autoloader. The detection adapter of the autoloader includes a second conditioning board and a second adapter housing. The main function of the second conditioning board is to condition the input and output signals, including isolation, amplification, reduction, etc., so that the signal can be within the range of the host acquisition signal. It can protect the host as well, when the acquisition signal is abnormal, at the input of the signal, it is limited to the safe range of the mainframe’s signal acquisition, then the mainframe and the autoloader’s detection adapter are not irreversibly damaged. The second adapter housing is composed of a second upper cover, a second lower housing and a second panel connector, which is mainly used to install the second conditioning board and install the second panel connector, as well as to protect the second conditioning board. The second panel connector is used to connect the resource cable of the host resource, and the detection cable of the signal connector of the autoloader.

### 2.2.4. Composition and function of cables

The main function of cables is to connect. In order to enable the test equipment to work, the cables connect the mainframe, the test kit/detection adapter, the component under test and the peripheral equipment in series. Cables include detection cables, tee cables, resource cables, communication cables and power cables. The detection cable is the cable that connects the test kit/detection adapter to the component under test and is used to transmit signals from the component under test into the test kit/detection adapter. The tee cable is the cable that connects the component under test to the detection cable and is used to lead the signal out while the component under test remains in its original operating state. The resource cable is the cable that connects the mainframe to the test kit/detection adapter and is used to transfer the signal from the host to the test kit/detection adapter for conditioning and then transmit into the mainframe. The communication cable is the cable that connects the peripheral devices, mainly used to connect the products of USB peripherals and network peripheral products. The power cable is the cable that supplies power to the host computer.
3. Working principle of the testing equipment

The test equipment is connected to the online test port via a tee cable and a detection cable according to the needs of the component under test. It transmits the signal of the component under test through the detection cable to the detection kit of the gun control box or the detection adapter of the autoloader. After being processed by their conditioning board, the signal is transmitted through the resource cable to the mainframe of the test equipment, where it is collected by the multifunctional acquisition module in the mainframe. The signal is then transmitted to the CPU module for analysis, which monitors the online working status of the tank’s gun control box/autoloader and stores the data in real time in order to judge the working condition of the component under test and to display the working condition through the touch screen. When an abnormality occurs in the gun control system, the monitoring data of the abnormal time period is called up and the cause of the abnormality is analysed according to the data. The working principle of the test equipment is shown in Figure 2.

![Figure 2. The working principle of the test equipment](image)

3.1. Detection principle of the gun control box

When testing the gun control box, the detection cable is connected to the online test port of the gun control box. The vehicle and the gun control system are started or just the gun control system is started to allow the test equipment to start working to, making data changes inside the gun control box. The output signals are collected at the self-test port of the gun control box, including the signals of power and vertical amplification output from the gun control box; the signals of horizontal aiming, vertical aiming, horizontal power and vertical power from the console; the signals of horizontal angle, vertical angle, horizontal control and vertical control from the fire control computer during the steady image working condition; and the signals of strong loading condition during the loading condition of the fire control computer, etc. The above signals are transmitted to the detection kit of the gun control box through the detection cable, and then through the conditioning by the conditioning board in the detection kit of the gun control box, such as isolation, reduction or amplification, the voltage value is within the range that can be collected by the multi-functional acquisition module. The signal is then transmitted via the resource cable to the mainframe of the test equipment, where it is collected by the multifunctional acquisition module and then transmitted to the CPU module, after which it is analysed and processed by the CPU module and displayed on the touch screen, and stored in the test equipment in real time.

When the gun control system is working abnormally, the data collected by the test equipment during the abnormal time period of the gun control system can be called out. The data stored by the test equipment is stored in chronological order. After confirming the abnormal working time of the gun control system, the test data within that time period can be quickly located and exported to an
external device via the USB port or the network port, and then the data can be analysed and compared through the relevant software to arrive at the cause of the abnormal working of the gun control system.

3.2. Detection principle of the autoloader
When testing the autoloader, the test equipment is connected to the signal connector of the autoloader by means of a tee cable and a testing cable. By starting the vehicle and activating the autoloader components or just the autoloader components, the test equipment starts to work. Then, the autoloader components are operated to cause data changes inside the autoloader. Next, output signals are collected at the signal connector of the autoloader, including ammunition selection signals from the fire control computer, control signals from the gunner console, control signals from the hoist, control signals from the pusher, control signals from the shell thrower, manual/automatic signals, as well as signals of raising-dropping, unlocking, unloading, opening window in place, closing window in place, etc. The above signals are transmitted via the detection cable to the detection adapter of the autoloader and then isolated, reduced or amplified by its conditioning board so that the voltage values are within the range that can be collected by the multifunctional acquisition module. The signals are then transmitted via the resource cable to the mainframe of the test equipment, where they are collected by its multifunctional acquisition module and then transmitted to the CPU module, after which they are analysed and processed by the CPU module to be displayed on the touch screen and stored in real time by the test equipment [3].

When a component of the autoloader is working abnormally, the data collected by the test equipment during the abnormal time period of the autoloader component can be called out. The data stored by the detection device is stored in chronological order. Therefore, once the abnormal operation time of the autoloader component has been confirmed, the test data can be quickly located and exported to an external device via the USB or network port. After that, the data can be analysed and compared through the relevant software to arrive at the cause of the abnormal working of the autoloader [4].

3.3. Principle of the acquisition and conditioning circuit
The DC signal acquisition and conditioning circuit is part of the detection and conditioning board and is used for the acquisition of DC voltage signals, including protection circuits, sub-compression small circuits and filtering circuits. The input conditioning circuit for the DC signal is shown in Figure 3. The DC voltage signal from the component under test is transmitted to the test kit or detection adapter via the detection cable. As the DC voltage signal directly from the component under test is not within the acquisition range of the multifunctional acquisition module, it needs to be reduced by conditioning so that the voltage value can be within the acquisition range. The conditioned DC voltage signal is transferred to the multifunctional acquisition module via the resource cable and then to the CPU module, and finally displayed on the touch screen after having been calculated and processed by the CPU module [5].

![Figure 3. The input conditioning circuit for the DC signal](image-url)
The AC signal acquisition and conditioning circuit is part of the detection and conditioning board and is used for the acquisition of AC voltage signals, including protection circuits, sub-compression small circuits, AC-DC conversion circuits and filtering circuits. The input conditioning circuit for the AC signal is shown in Figure 5. The AC voltage signal from the component under test is transmitted via the test cable to the test kit or test adapter. As the AC voltage signal directly from the component under test is not within the acquisition range of the multifunctional acquisition module, the multifunctional acquisition module cannot directly acquire the AC voltage signal. Therefore, the AC voltage signal needs to be conditioned for reduction and AC/DC signal conversion so that the AC voltage signal is converted into a DC voltage signal within the acquisition range of the multifunctional acquisition module. The AC input is first passed through a transient voltage suppressor to ensure that the input signal is within the input range of the conditioning circuit, then divided and attenuated to the voltage input range of the AC acquisition chip, which converts the differential signal into a single-ended signal to complete the acquisition of AC voltage. The conditioned AC voltage signal is transmitted to the multi-functional acquisition module via the resource cable and then to the CPU module, and finally displayed on the touch screen after having been calculated and processed by the CPU module.

The digital signal acquisition and conditioning circuit is part of the conditioning board and is used for the acquisition of switching signals. The digital signal acquisition and conditioning circuit is shown in Figure 4. The switching signal has no explicit input variation, is +26V when there is an output, hangs or is grounded when there is no output and the output voltage is 0V. The switching signal output from the component under test is transmitted into the detection adapter through the detection cable, and after conversion by the opto-coupler on the conditioning board, it is transmitted through the resource cable to the multi-functional acquisition module. After being collected by the digital IO interface of the multi-functional acquisition module and transmitted to the CPU module, the signal is finally calculated and processed by the CPU module and displayed on the touch screen.

![Figure 4. The input conditioning circuit for the AC signal](image-url)
4. Testing
After completing the development of the test equipment, this study docked it to the actual equipment components and carried out condition tests as well as fault diagnosis trial tests. In this process, the actual equipment were technically intact components, and the test equipment was continuously switched on for not less than 8 hours per day. The experimental results show a normal working state, indicating that the test equipment has passed the evaluation and met the design requirements of functions. After the condition test, a fault diagnosis trial test was carried out. According to the number of signals of equipment components, one or more fault points were set to test the equipment components. The main fault setting method was achieved by disconnecting the access cable of the relevant signal or by changing the original state of the corresponding switch or key. A total of 6 components and 10 common faults were tested in the fault diagnosis test. It was verified that the testing and repair process can accurately locate faults in the key functions of the equipment components.

5. Conclusion
The testing equipment designed in this study is in response to a series of problems that exist in the actual use of tank fire control systems and autoloaders, such as many sudden failures, difficulties in fault diagnosis and location, and complex maintenance and security. It realizes the monitoring of the working condition of the gun control box and the auto-loader components of a certain type of tank, and has the following advantages.
(1) It can carry out comprehensive testing of the fire control system and the autoloaders, meeting the needs of system integration.
(2) The parameters of the system status can be monitored in real time, enabling accurate diagnosis of faults that are difficult to reproduce and solving the problem of not being able to obtain test data in real time, resulting in the inability to fully assess the technical status of the equipment due to insufficient data acquisition.
(3) Test data can be exported, backed up and queried, which improves the convenience and long-term use of monitoring data and facilitates long-term, mass accumulation of data as well as analysis and research of fault patterns.
(4) It has a fast measurement speed and high detection accuracy, meeting the requirements of fast and efficient detection.

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