The Research on the Test Technology of Ammunition-feed System Based on the Integration of Shooting Simulation and Driving Simulation

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Abstract. Ammunition-feed system is a key system in special vehicles equipped with shooting weapons (such as main battle tank, self-propelled artillery, etc.). The working reliability of ammunition-feed system is very important for the operation of special vehicles. However, in terms of the use of ammunition-feed system of special vehicles in active service in various countries around the world, its reliability is often not satisfactory, which is the main reason that ammunition-feed system has not been adopted in American main battle tanks up to now. Firstly, the paper points out that one of the main causes of the poor reliability of ammunition-feed system lies in the problems existing in the traditional test methods, these problems are analyzed concretely, and puts forward the solution. — The test technology is adopted based on the integration of shooting simulation and driving simulation. Then, the paper states based on the basic concept of the test of technology of shooting simulation and driving simulation and type of simulation test device, working principle, basic function and technical characteristics, and This paper puts forward the concrete implementation of the integrated test technology of shooting simulation and driving simulation in the performance test of ammunition-feed system in special vehicles, and analysis of effects is applied. Finally, the conclusion is drawn that the application of the simulation test technology will improve the overall performance of the ammunition-feed system significantly.

1. Introduction
Ammunition-feed system (AFS) is an important component of fighting vehicles such as modern tanks, self-propelled guns (collectively referred to as "special vehicles"). AFS performance test is one of the main content of the special vehicle overall performance experiment. the advance of test technology or not is directly related to the development progress, cost investment, the accuracy of performance evaluation and the reliability of the column packed, and mainly displays in:

On the one hand, with the rapid development of ordnance science and technology and the continuous improvement of automation level, the consumption of research, development and test of special vehicles has increased rapidly, and the cycle of development and mounting has been extended long accordingly. Among them, the cost and time of AFS test account for more and more in the whole development process.

On the other hand, the traditional test methods for the performance of AFS can no longer fully meet the increasingly improved reliability and other performance requirements. For example, among the overall of AFS performance appraisal process, the real vehicle test is necessary, but according to
tradition, the whole real vehicle experiment process are divided into chassis driving and weapon shooting two parts (shoot test subjects have to move to move shooting, but the number of projectile rarely). Although it exists mainly affected by the condition such as budget and schedule, but it will inevitably lead to test the consequences of inadequate, not timely, fully exposed only riding and shooting (vibration and shock) long time the reliability of the mutual coupling effect which will appear problem. This is also the main reason why the reliability of AFS is not obvious in the early stage of the sample vehicle and mass production vehicle, but it has long troubled the equipment in service in many countries (such as Japanese type 10 tank and Korean type K9 self-propelled gun).

In order to adapt to the requirements of the development of the overall technology of modern special vehicles, it is necessary to explore and apply more economical, efficient, comprehensive and full integration of driving and shooting test technology in the test of AFS. Based on that, the paper discusses a new test technology of AFS -- integrated test technology of launching simulation and driving simulation and its application in system research from the perspective of overall performance assessment and application evaluation.

2. The test method and existing problems of traditional AFS

2.1. Traditional test method for AFS
The traditional test methods for AFS mainly include platform test and real vehicle test, both of which have some problems.

Platform test is usually carried out indoor, before assembly. Currently adopted by the test platform almost is stationary. The test content for AFS normally only has the function of basic movements and preliminary debugging, validation, but in the special vehicle moving shooting, shock vibration condition (especially the ultimate gesture), and different attitude, the work performance of AFS can’t be assessed dynamically and synthetically.

Real vehicle tests must be carried out the vehicle's off-road driving and live firing, especially to the inspection for the AFS’s continuous working performance and reliability. It needs to consume large amounts of fuel, ammunition, and high cost, long cycle. It’s very difficult for AFS’s working status, performance testing, and fault finding, diagnosis, and ruled out.

2.2. The embodiment of real vehicle test problems

2.2.1. High test cost. During the real vehicle test, a large amount of ammunition is fired to evaluate the performance of the AFS (especially the automatic working continuity). For example, to assess the work reliability (MNBF) of an improved AFS whether meets the requirements of the average failure to send the number of indicators. To fully test data, and give attention to both economy, even though according to the standard recommended by taking less time testing scheme, also need to projectile thousands of ammunition, such ammunition spending is needed at least tens of millions of RMB, if considering live firing test, field, all kinds of service for staff and other consumption, it is more significant to do the reliability test of the expenses.

2.2.2. Long test cycle. Before and after the firing test of live ammunition, the whole AFS must be checked statically. According to the different complexity of its structure, each static test will take a lot of time, and it generally needs to be checked statically once before and after the test. In order to ensure the safety of personnel and equipment, it is necessary to clear the field before each firing of live ammunition, which generally needs to be carried out in the daytime, and the effective test time is limited every day. In order to ensure the normal operation of weapons, after a certain number of shots, it is necessary to carry out comprehensive maintenance of weapons and AFS. If factors such as weather and ammunition preparation are taken into consideration, the whole test cycle of AFS is also very considerable.
2.2.3. Difficult in performance evaluation. "Five characteristics (reliability, maintainability, safety, testability and supportability)" is difficult to evaluate. Modern requirements on the "five characteristics" index system of AFS are becoming more and more systematic. However, the assessment of "five characteristics" requires a large amount of test data to fully expose the design, usage and maintenance of AFS. These data obtained from live ammunition firing in traditional tests are far from satisfying the requirements of result evaluation.

When firing live ammunition, it is very difficult to examine the impact, vibration and other performance parameters of AFS and its mechanism under the limit conditions of negative Angle and large Angle of fire of special vehicles. Once there is a misfire bomb in the test process, it will be very troublesome and dangerous to eliminate it. In addition, due to the small space in the car, except for the crew, it is difficult for the test and technical personnel to approach during shooting, so it is difficult to find, locate, analyze and eliminate the fault in time, which is particularly prominent for the newly developed AFS.

In order to solve the problems of the above traditional test methods, the application of simulated launch test technology in the overall performance test will be an economical, practical, fast, efficient and comprehensive technical approach.

Driving simulation (also known as "road simulation") test technology is widely used at present. The technology of shooting simulation test developed relatively late, and its application is narrow.

3. simulated emission test technology

3.1. Launch and recoil

During the shooting of weapons such as artillery, under the action of gunpowder gas, the gun barrel and the tail of the gun move in the opposite direction of the movement of the projectile. The movement of the projectile forward is called launch, while the barrel and the tail move backward. The action is called recoil. For the artillery, the force of the gunpowder gas acting on the barrel during the recoil and the direction of the projectile along the axis of the barrel is called the resultant force of bore, and the resultant force of the gun passes through the buffer energy-absorbing device (reverse recoil device) on the launching device. The force on the turret and chassis of the special vehicle is called the recoil resistance. Since the gas pressure in the crucible is extremely high when the gun is fired (the maximum rolling pressure is even hundreds of MPa), the combined force of the gun is extremely great.

In order to reduce the direct effect of the gas pressure on the launching device, the modern artillery is equipped with a reverse recoil device, which divides the resultant force of bore into two parts, one part is the inertial force of the recoil movement and the other part is the recoil resistance. In this way, the squat resistance is much smaller than the resultant force of bore (only 1/20 to 1/40), ensuring the stability of the firing and the strength of the launching device, reducing the mass of the launching device, reducing its structural size, and improving the maneuverability of the artillery system.

As far as special vehicles are concerned, the most concern is the recoil resistance of the gun when it is launched. This squat resistance is the impact load of the special vehicle turret and even the chassis during the shooting. The magnitude of the impact load is directly related to the action time. A series of overall performance indicators such as shooting accuracy, shooting stability, firing rate, length of the gun, length of the structure, and even the volume and weight of the vehicle. Although the recoil resistance has been made to be much lower than the resultant force of bore by the anti-rear device, the force is still very large for the special vehicle, and the reliability problem for the bullet system is caused by the impact load.

3.2. Basic concepts of simulated emission test technology

The simulated launch test technique refers to a test device that can simulate the squat resistance generated by the cannon firing, so that the tested artillery or artillery simulation device produces the same recoil dynamic effect test technique as the live projectile, which includes a complete set of simulated launch test devices. test methods and methods.
Using this test technology, it is possible to simulate the impact and vibration of the weapon launch on the entire special vehicle in the laboratory, and the working conditions of each main component except the gun barrel of each system (including AFS), and its resistance Comprehensive assessment of impact and vibration performance.

3.3. Research Status of Simulated Emission Test Technology
At present, there are many units in China, such as the Armored Force Engineering College, the Ordnance Engineering College, Nanjing University of Science and Technology, North University of China, Harbin Institute of Technology, Huazhong University of Science and Technology, all of which have carried out simulated launch tests (or "artillery launch impact load simulation test") Technical research, some units have also developed physical prototypes. Many domestic research units are mainly colleges and universities. The common feature of research is that heavy weapons are same, but are different in population, and more research and less application.

There are few foreign data on the simulation of emission test technology, only a few related papers have been found, and the discussion is not very detailed.

3.4. Types and working principle of simulated emission test equipment

3.4.1. Types of current simulated launch test devices. The simulated launch test device is divided into: explosive type, hydraulic type and pneumatic type according to the different applied dynamic load source; according to the different parts of the load, it is divided into: muzzle impact type and rear end pull type.

3.4.2. Working principle

1) Explosive

The explosive type simulation test device is similar to a gun. The gunpowder is used as the energy source. During the simulation test, the gunpowder is burned in the drug chamber of the impulse tester of the simulator. The gunpowder gas is generated on the piston and acts on the piston through the other end of the piston. The shell of the artillery shell was tested and the impulse was transmitted to the tested artillery to make the recoil part produce a recoil movement to achieve the same recoil dynamic effect as the live shot. Through the adjustment and matching of the parameters of the simulation test machine, the simulation test machine can perform dynamic squat simulation test on a variety of large and medium caliber guns with anti-rear device, and has high simulation accuracy (the simulation error of main parameters is not more than 5%).

2) Hydraulic / pneumatic

The hydraulic analog emission test device (shown in Figure 1) converts the hydraulic energy into an instantaneous strong impact force acting on the recoil portion of the gun to realize the recoil movement of the gun. The hydraulic simulated emission test device usually includes two main components: a hydraulic power subsystem and an impact subsystem. The function of the hydraulic power subsystem is to generate a large flow in a very short time, and the mass of the piston rod of the hydraulic cylinder is driven. At high speeds, when a certain speed is reached, the piston rod and the mass are disengaged. The impact subsystem is mainly composed of a mass block and a buffer. Its function is to transmit the kinetic energy to the squat portion of the gun through the impact of the mass block and the muzzle buffer to provide energy for the squat of the gun. The mass is then reset under the action of the return device to prepare for the next impact.

The pneumatic working principle is basically the same as that of the hydraulic type, and is more suitable for simulating the launch of a slightly smaller caliber.
3.5. Basic functions of the simulated emission test device

1) Simulated recoil: simulates the dynamics and kinematics of the recoil of the artillery;
2) Extreme shooting: simulates the firing conditions of the artillery in the required direction and high and low shooting range;
3) Load adjustment: The impact load can be adjusted according to the model of the simulated gun and the different recoil generated by the propellant;
4) Automatic alignment: It can automatically adapt to the change of the position and angle of the gun barrel, so that the impact direction is always centered with the body tube axis.

4. Application of integrated test technology of simulated launch and simulated driving in performance evaluation of AFS

4.1. Specific implementation plan

4.1.1. Plan 1: On the basis of the experimental device of normal driving simulation (also called "road simulation") equipped with launch simulation test device, which constitute a special vehicle for AFS dynamic test bed (figure 2), it can be equipped with AFS of special vehicles or test framework in the test which will be tested. Through the simulation test device for driving the input of road surface spectrum, at the same time through simulated firing device of artillery exert impact load, to simulate moving gun shooting for the impact of AFS.

This combination is to assess the motion state of the special vehicle at different azimuth angles, so there are two different layout forms. One is to design the position of the simulated launcher to rotate relatively around the test bed instead of rotating it (figure 3a). The other is that the driving simulator can rotate while the simulated launch tester is installed at the same position on the ground (figure 3b). These two kinds of layout form have advantage each, which specific case can be inspected to decide to use what kind of layout form.
4.1.2. **Plan 2:** Based on the six degrees of freedom, simulation test devices are launched on bench which constitutes another form for AFS overall dynamic test bed (figure 4). It can be placed in prototype test bench for AFS, through the six degrees of freedom of turret weapon of vibration test rig simulation pavement, through the simulation of recoil mechanism simulation artillery to lose on the impact of AFS.

This combination is relatively simple because the main body of the six-degree-of-freedom test bed and the simulated launch test device are relatively fixed and do not need to adjust the space position.
4.2. Effect analysis of technology application

4.2.1. Technical characteristics
1) time saving: it can significantly shorten the development cycle;
2) cost saving: the cost of research and development investment can be greatly reduced;
3) comprehensive assessment: the overall performance of the AFS and its components can be assessed and evaluated;
4) convenient test: the test process can be comprehensively monitored without the access of test personnel;
5) easy to expand: it can be easily combined with the fire control system test bench and the walking system test bench;
6) extensive application: it can be applied to special vehicles equipped with AFS, such as tanks and self-propelled artillery.

4.2.2. Military benefits
1) it can more comprehensively and accurately assess the working performance of the newly developed AFS, and provide sufficient, reliable and scientific basis for the overall scheme optimization and the optimization of several schemes. Specific test assessment contents mainly include:
   (1) overall performance assessment of AFS under moving firing condition;
   (2) overall performance assessment of AFS under shooting conditions in the limit range;
   (3) evaluation and optimization of multiple schemes of the newly developed AFS;
   (4) performance test of newly developed AFS components;
   (5) evaluation of modification effect of AFS.

4.2.3. Economic benefits. It can save a considerable amount of ammunition and other consumption for the study of AFS, shorten the development period and reduce a lot of development cost.

5. Conclusion
From what has been discussed above, through the simulation and road simulation test and form of the combination of AFS dynamic test technology, it can be widely used in special vehicle for AFS overall performance evaluation and assessment, broad application space. It can achieve significant military, economic and social benefits, so it is necessary to further research and application.
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