Smart projectile acceleration testing in harsh launch environment

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Abstract: In order to solve the problem of parametric test of smart projectile launch, the launch environment of smart projectile was analyzed. a reasonable and feasible storage testing method was proposed, and a multi-channel test system suitable for the environment was designed. The system was successfully applied to a certain range test, and dynamic parameters such as triaxial acceleration of smart projectile launch environment were acquired. The test results play an important role in the improvements of smart projectile design process.

Key words: launch environment; smart projectile; store testing; tri-axial acceleration

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0 Introduction

The study on the acceleration parameter test of smart projectile is important for dynamic test technology in military field. Currently smart projectile is mainly used to target at objects of great value, and it develops very fast. But there are some problems during the improvement. By adopting advanced and reliable testing methods[1], some first-hand data were provided to solve these problems. Due to the harsh launching environment, we can not take the previous testing methods, and there is seldom study abroad and at home. We adopt storing test to solve these problems in this paper. We propose a specialized on-board testing system based on the full understanding and analysis of the characteristics of the tested signal and its environment in order to not only get an exact and reliable parameter test, but also minimize the impact of the environment.

1 Analysis of launch environment

The whole process operation of smart projectile includes 6 stages: preparation, loading, triggering, moving to the muzzle, shooting and targeting. At each stage, it gets forces from different causes to promote the normal movement or destroy the structure of the projectile, resulting in some abnormal or unusual distortion and movement, even the disintegration[2,3].

The study is targeted at testing the acceleration of smart projectile at the stages of triggering and moving to the muzzle. Its feature is several stimulus signals caused by triggering pressure, three-dimensional impact, rotational centrigugal force and so on. And the testing system is used to test these signals. In order to obtain a correct testing method, we must analyze the force of smart projectile at each stage and its changing rules.

As shown in Fig. 1, smart projectile has a band which can cause rotation of the projectile.

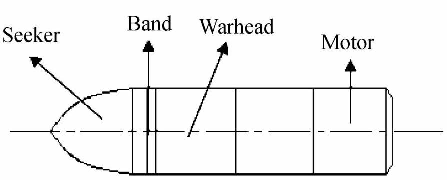

Fig. 1 Schematic diagram of terminal-guided shell

During launch, parts of the end and head get different forces which cause deformation of projectile within the bore, resulting in the strong vibration of guidance parts at the head of the projectile and much

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radical load.

The process is simulated by means of ANSYS, and a simulation model is obtained as shown in Fig. 2, which shows a clear bent deformation. This radical overload has an unneglectable effect on the projectile movement to be tested.

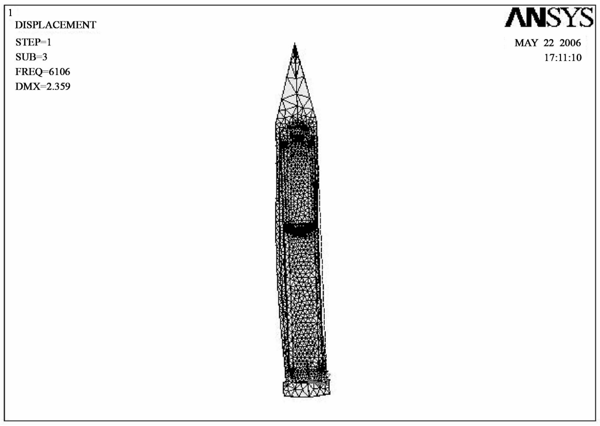

Fig. 2 simulation model of bent projectile

2 Testing method

The whole testing operation process of the terminal-guided shell is shown in Fig. 3. The storage testing method is proposed according to the testing process[4].

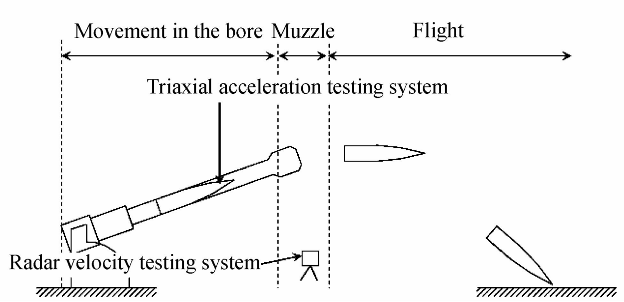

Fig. 3 Schematic diagram of testing process

2.1 Analysis of testing stages

The whole testing process includes three stages of in the bore, at the muzzle and flight. We designed different sampling strategies at different stages. The first two stages were combined as one stage to design sampling strategy because of the close link between them.

2.2 Test object and system composition

Triaxial acceleration consists of one axial acceleration and two radial accelerations with intersection of 90°. The whole testing device of the smart projectile aims to test triaxial acceleration of four parts during launching. We collect all the data at the end of each stage.

The features during the whole testing environment are as follows:

1) High overload: 10 000g in the bore, and 30 000g upon hitting;

2) High temperature: 3 000 ℃ of instantaneous high temperature, −20 ℃ during movement, 50 ℃ at preservation process;

3) High pressure: 300 MPa in the bore.

The block diagram of circuit module of testing triaxial acceleration is shown in Fig. 4.

It contains sensor array, test circuit, high intensity mechanical protective enclosure and battery. Sensor array is made up of triaxial acceleration sensor[5]. When transmitted into the circuit through sensor array, testing signals are processed and stored, and then sended to computer. During the whole test, the sampling frequency in each passage is 200 kHz, the measuring range of sensor is 30 000g, and the whole testing system is connected to the thread of smart projectile.

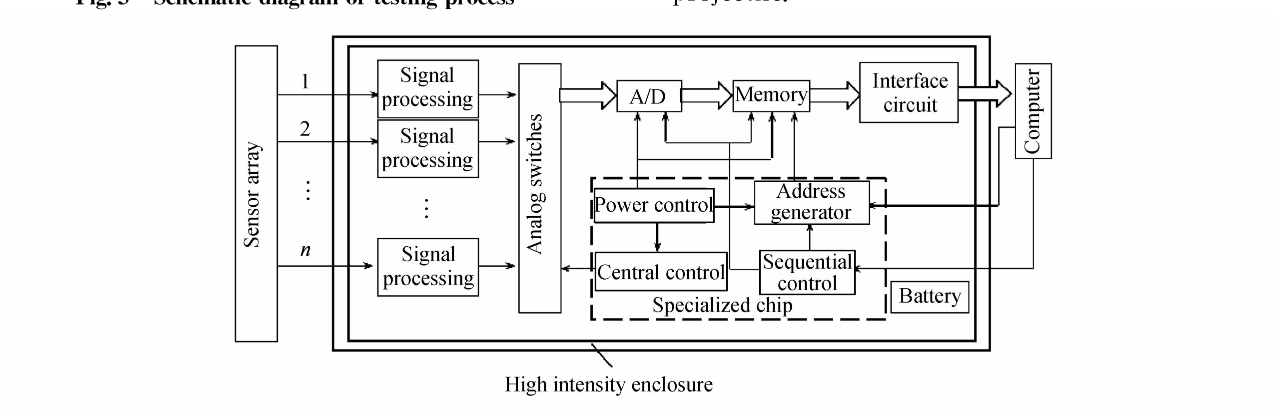

Fig. 4 Block diagram of testing system

After connected to the power, the testing device is installed in the bore of the projectile together with the terminal-guided shell. At first, we use the baseline signals of different magnifications taken from high-speed sampling frequency as reference to the final data analysis, then cyclically sample by way of high-speed sampling frequency and high magnification[5-6], waiting for the triggering signal within the bore. When launched, the projectile is accelerated within the bore by the push of gunpowder gas. The testing device is started by the positive acceleration and records signals from different directions, which can ensure the shift vary from high magnification of high frequency to low magnification of low frequency when all the signals in the bore and at the muzzle are recorded. Then the projectile is slowed down until it lands because of air friction, and then the testing device saves the data in the form of low power[7].

3 Data analysis

The actual testing of axial acceleration curve of terminal-guided shell is shown in Fig. 5. It shows that the curve is consistent with the theoretical analysis; the actual testing strong vibration curve is highly related with installation place and its installation way of the acceleration sensor. Because the acceleration of the bore is caused by the pressure from the bottom of projectile, there is strong correlation between axial acceleration and bottom pressure in the projectile. They vary with the change of time, therefore, when there is the maxim bottom pressure, the maxim axial acceleration will produce.

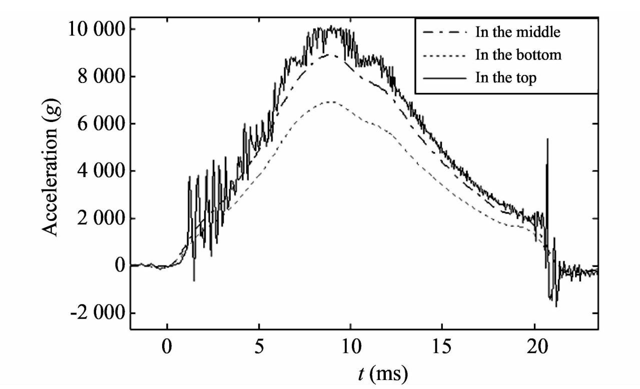

Fig. 5 Axial acceleration curves of different parts

3.1 Axial acceleration

As shown in Fig. 5, as time goes from 1.961—1.961 5 ms, the gunpowder is ignited and produces massive gas which pushes the projectile into the band. And then the rifling cuts off the band, pushes the projectile forward resulting in a step of positive acceleration. The projectile clashes with the band constantly, causing vibration within all parts of projectile.

At the time of 1.961 5—1.964 5 ms, the projectile moves forward along the band. At 1.962 5 ms, the pressure in the bore reaches the maximum, and so does the axial acceleration. After that, the acceleration starts to reduce. At 1.962—1.963 5 ms, the axial acceleration declines first and then increases, which is caused by the unstably change of acceleration during burning, because of 3 kinds of gunpowders installed in the projectile.

During 1.964 5—1.965 5 ms, the projectile entries the gas ejection period. It flies out of the muzzle. At the same time, the sudden change of gunpowder gas causes a negative step force to the bottom of projectile.

Different shapes of curves represent the changes at different axial accelerations of projectile. The vibration curve changes strongly most, which is got from the testing device near the head of projectile. This is well matched with the great acceleration change caused by the clear bent deformation of projectile as shown in Fig. 2. Namely, the closer it comes near the head of projectile, the better the features are in response to medium-high frequency.

3.2 Radial acceleration

Fig. 6 is the actually radial acceleration curves. They show a clear vibration of the projectile when it is squeezed into the band, and a strong vibration almost over 2 000g occurs when the projectile is ejected out of the muzzle. This is similar to the changes of axial acceleration.

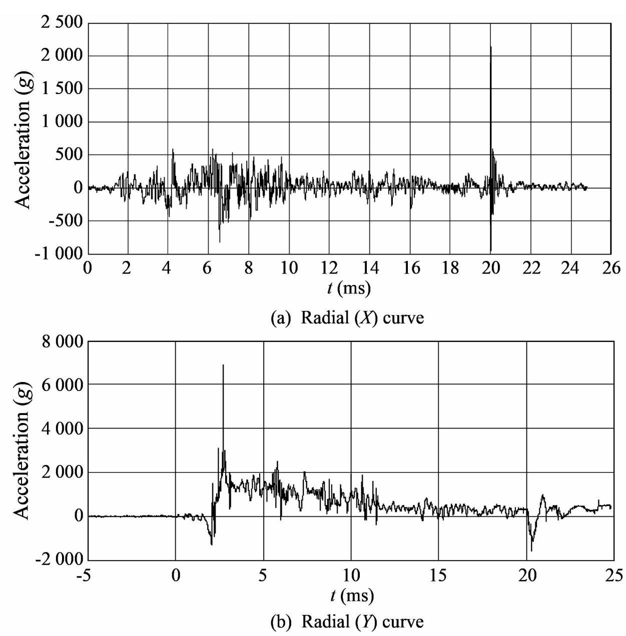

Fig. 6 Radial acceleration curves of smart projectile

4 Conclusion

This article completes the launch environment test through storing testing. A testing method is proposed by studying the features of signals tested. A detailed account of the component of testing system, the selection of testing strategy and the analysis of testing results are described in detail. The results in the shooting range provide first-hand experiment data for the design, production, remodeling and the other developing processes, and also offer data support to the study of the testability, reliability, survivability and credibility of system.

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恶劣发射环境下灵巧弹丸加速度测试研究

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摘　要： 为解决灵巧弹丸发射时参数测试的问题，针对恶劣发射环境下灵巧弹丸进行了分析，提出了合理可行的存储测试方法，设计了适合该环境的多通道测试系统。该系统被成功应用于某靶场测试，并获取了灵巧弹丸发射环境三轴加速度等动态参数。该测试结果在灵巧弹丸改进设计过程中具有重要的作用。

关键词： 发射环境；灵巧弹丸；存储测试；三轴加速度

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