Research on Test scheme for Anti-Jamming Performance of Self-Seeking Anti-tank Missile

Jinlong Ma, Liyuan Ma, Dan Fang

Shijizhuang campus of the army Engineering University,No.97,hehe West Road, Xinhua District, Shijiazhuang,hebei， 050003, China

Abstract

The guidance accuracy of the anti-tank missile weapon system depends largely on the performance of the guidance control system. In the final test and identification of missile weapons, it is necessary to test and analyze whether the performance of the guidance control system meets the requirements of the combat technology. Commonly used test systems can only test the functional results of the missile guidance control system, and cannot quantitatively describe the pros and cons of its performance. In order to test the performance of the anti-tank missile guidance and control system more comprehensively and scientifically, this paper proposes a combination of mathematical simulation and semi-physical simulation based on the semi-physical real-time simulation technology.

Keywords

Guidance system, performance test, evaluation method, miss distance.

1. Introduction

The test and identification of the missile weapon system, it is necessary to test and evaluate whether the performance index of the missile meets the requirements of the tactical missile. The performance test of the guidance system (without the seeker, which will not be described later) is a very important part. The guidance precision of the missile depends largely on the performance of the guidance system. At the same time, the guidance accuracy directly limits the killing effect of the weapon. Therefore, how to effectively test the performance of the missile guidance system is very important. At present, in the design process of missiles, the performance of missile guidance system is usually analyzed by single target such as miss distance and overload, and only mathematical modeling analysis is used to give conclusions. The results obtained by this method based on a single indicator analysis have great limitations [1] and do not fully reflect the performance of the missile guidance system. In order to more accurately give the performance measurement of the missile guidance control system, it is often necessary to analyze and evaluate through multiple indicators[2]. In the 1960s, the United States put forward the theory and method of comprehensive experiment, and it was widely used in the field of space and weapon system simulation. The semi-physical real-time simulation was widely used in the development of Patriot missile, tail-stab missile and rattlesnake air-to-air missile. Technology, greatly reducing the number of target tests.

The simulation test technology is a high-tech test method developed with the development of new technologies such as computer technology, automatic control technology and information processing technology, and has been widely used. In particular, it played a huge role in the design and development of guided weapons. In the weapon test identification, simulation technology has also been started, and its unique advantages and huge military and economic benefits have been shown. Scientific and effective application of simulation technology for weapon test identification is an important aspect of the future development of test technology。

2. Design of mixed interference scheme

In the shaping stage of the missile, the model finally provided by the manufacturer has been very reliable, and the mathematical model at this time is generally considered to be very credible. The design of the semi-physical simulation scheme that can be analyzed by mathematical model is very necessary, and the results of the mathematical model can also verify the correctness of the semi-physical simulation test results. There are many interference factors affecting the performance of the missile. In order to simplify the analysis process, this paper only analyzes the four main types of interference. The four main disturbance factors are the upper and lower limits of the pneumatic parameters, wind interference, structural interference, and attitude angle deviation. For ease of analysis, the interference factors can be classified into A (structural interference), B (pneumatic interference), C (engine deviation), and D (wind bias interference).

In this paper, a hybrid interference scheme is designed based on the orthogonal analysis method. A four-factor and three-level orthogonal analysis table is proposed. The orthogonal analysis method is a mathematical analysis method, and its key lies in the establishment of orthogonal tables and the determination of factor level values. Set the level values of each interference amount as shown in Table 1, and the mixed interference scheme settings as shown in Table 2.

Table 1: Orthogonal level values

Interference amount	Structural interference (kg, kg/m^3, kg $*$ m^2)			Pneumatic interference（n $*$ s/kg）			engine deviation（°）	wind(m/s)
	Quality	density	Rotate Inertia	Inertia lift	Coefficient of resistance	Coefficient of pitching moment		
1	0.25	8%	15%	20%	20%	10%	0.1	2
2	0	0	0	0	0	0	0	0
3	-0.25	-8%	-15%	-20%	-20%	-10%	-1	-2

The target of anti-tank missiles is usually tanks or armored vehicles, and the speed is generally 18m/s. Since the anti-tank missile has a relatively short flight distance, the motion state of the target does not need to be considered complicated. Usually, the accuracy of the hitting in the linear motion is evaluated, and the direction of the linear motion will produce different results, so it is necessary to separately test and analyze. It is perpendicular to the missile launching direction and the relative missile launching direction. Here, it is called linear motion (vertical) and linear motion (horizontal). In addition, the initial distance of the projectile is also an important factor affecting the accuracy of the hit, especially the bullet. In the very close range, the missile has a short flight time, leaving less time for controlling and adjusting the direction of the missile, which easily causes the missile to miss the target.

There is orthogonality between the test programs, and it is easier to analyze the main interference and the secondary interference. According to the orthogonal test table, the interference combination method is set, and combined with the simple and reliable characteristics of the orthogonal analysis table, the specific influence degree of the relevant interference amount on the miss target can be scientifically and efficiently analyzed.

Table 2: Mixed interference scheme

Interference amount	Structural interference (kg, kg/m^3, kg $*$ m^2)			Pneumatic interference（n $*$ s/kg）			Attitude angle（°）	wind(m/s)
	Quality	density	Rotate Inertia	Inertia lift	Coefficient of resistance	Coefficient of pitching moment		
1	0.25	8%	15%	20%	20%	10%	0.1°	2
2	0.25	8%	15%	0	0	0	0°	0
3	0.25	8%	15%	-20%	-20%	-10%	-0.1°	-2
4	0	0	0	20%	20%	10%	0°	-2
5	0	0	0	0	0	0	-0.1°	2

6	0	0	0	-20%	-20%	-10%	0.1°	0
7	-0.25	-8%	-15%	20%	20%	10%	-0.1°	0
8	-0.25	-8%	-15%	0	0	0	0.1°	-2
9	-0.25	-8%	-15%	-20%	-20%	-10%	0°	2

3. Overall design of the simulation test plan

The weapon test is a comprehensive test of the quality and performance of the weapon in compliance with the specified requirements. Through inspection, inspection and testing, the performance parameters of the weapon system are obtained, and the obtained data are analyzed and studied. The conclusion is drawn as to whether the weapon meets the tactical technical requirements, and the utility and effectiveness of the weapon system are estimated. Type and equipment forces provide the basis. In the design, the anti-interference ability test of the missile guidance control system is generally carried out by mathematical simulation, semi-physical simulation and flight test. Mathematical simulation can not detect the problems caused by inaccurate modeling, software defects on the missile, and insufficient performance of the hardware itself. The method of physical simulation measures the anti-interference performance of the guidance control system, which can not only overcome the problems of the software and hardware itself, but also can carry out a large number of Simulation experiments to obtain more accurate and accurate indicator information [8]. The flight test can only verify the performance of the control system under one or several specific actual flight conditions, does not cover all operational conditions, and can cost a lot of time. Therefore, when investigating the anti-interference ability of the guidance control system, the mathematical model and the semi-physical simulation should be fully utilized, so that the mutual verification can complement each other, the test result is more reliable, and the test time can be greatly saved.

In the design stage, the missile usually uses the simulation mathematical model to analyze the guidance control process. Only the mathematical method simulates the guidance error, and ignores many influencing factors. The simulation results are not enough to evaluate the flight quality of the missile. In this paper, the semi-physical real-time simulation technology is used to test and analyze the deviation between the actual attitude angle and the theoretical attitude angle during the missile simulation flight, to simulate the actual flight process of the missile to the maximum extent, and to ensure the scientific and reliable test results.

The results of mathematical simulation can not only measure the degree of influence of single interference, but also construct the interference combination of semi-physical simulation test reasonably, reduce the number of semi-physical simulations, save time and save cost. The specific implementation steps of this test plan:

(1): Verify that the communication of the semi-physical simulation network is normal;

(2): According to the order of the bombing machine and the inertial measurement unit, verify that the basic performance of the system is good and can work normally;

(3) Set the initial conditions of the simulation, carry out specific simulation tests, and do the off-target amount in the case of ten test combinations for each test state;

4. Semi-physical simulation test

In the shaping stage of the missile, the model finally provided by the manufacturer has been very reliable, and the mathematical model at this time is generally considered to be very credible. Therefore, the design of the semi-physical simulation scheme of the data result index analyzed by the mathematical model is very necessary, and the result of the mathematical model can also be used to verify the correctness of the semi-physical simulation test result. The six-degree-of-freedom full-quantity ballistic model of the guidance control system consists of a centroid kinematics equation, a centroid rotation equation, and a centroid dynamics equation. These equations are described in detail in various flight references and will not be repeated here [9].

The test results also prove that the semi-physical simulation test method designed in this paper is more realistic and reliable than the mathematical analysis. It is more comprehensive and perfect than the test system test, and the data results can be quantified as an important basis for the evaluation of the missile subsystem. This paper only analyzes the semi-physical simulation test method of the anti-tank missile subsystem and analyzes its performance simply. It is not deep enough in the target state analysis. The comprehensive performance evaluation based on the hardware-in-the-loop simulation data needs further research.

It can be seen from the orthogonal analysis table of the simulation results that the interference that affects the maximum amount of off-target is aerodynamic interference, and the smallest is structural interference. Among them, the miss amount of the target caused by the experimental scheme 9 is the largest, and the maximum and minimum values of the off-target are different. Most, the maximum is 0.28 meters, the minimum is 0.01 meters, which indicates that to measure the anti-interference ability of missile guidance control, we must choose the appropriate interference combination. Combined with the simulation results, it can be seen that the 9th interference combination scheme should be considered in the flight test verification.

Table 3: Mathematical Simulation Test Results

Interference amount	Structural interference (kg, kg/m^3, kg $*$ m^2)			Pneumatic interference (n $*$ s/kg)			Attitude angle (°)	wind(m/s)	CEP
	Quality	density	Rotate Inertia	Inertia lift	Coefficient of resistance	Coefficient of pitching moment			
1	0.25	8%	15%	20%	20%	10%	0.1°	2	0.06
2	0.25	8%	15%	0	0	0	0°	0	0.07
3	0.25	8%	15%	-20%	-20%	-10%	-0.1°	-2	0.11
4	0	0	0	20%	20%	10%	0°	-2	0.10
5	0	0	0	0	0	0	-0.1°	2	0.05
6	0	0	0	-20%	-20%	-10%	0.1°	0	0.18
7	-0.25	-8%	-15%	20%	20%	10%	-0.1°	0	0.01
8	-0.25	-8%	-15%	0	0	0	0.1°	-2	0.06
9	-0.25	-8%	-15%	-20%	-20%	-10%	0°	2	0.38

5. 5 Evaluation of anti-interference performance

The test evaluation of the anti-jamming performance of the missile guidance control system requires comprehensive mathematical simulation and semi-physical simulation data, and combined with mathematical simulation data to determine the specific value of the interference amount in the flight test. Combined with the test evaluation scheme described in this paper, an anti-tank missile is taken as an example to evaluate the anti-jamming performance of its guidance control system。

Under the premise of good data compatibility, stimating its distribution parameters (because the target is set to a fixed target, there is no deviation in the x direction).

Point estimate:

$$\begin{cases} \bar{y} = \frac{1}{n}\sum_{i=1}^{n} y_i \\ \bar{z} = \frac{1}{n}\sum_{i=1}^{n} z_i \end{cases} \tag{1}$$

Since in the case of two dimensions, and the standard deviation between the y direction and the z direction is not equal, the off-target amount at this time, that is, the circular probability error can be expressed as:

$$\begin{cases} \text{CEP} = 0.5887(\sigma_y + \sigma_z) \\ \sigma_y = \sqrt{\frac{\sum_{i=1}^{n}(\bar{y}-y_i)}{n-1}} \\ \sigma_z = \sqrt{\frac{\sum_{i=1}^{n}(\bar{z}-z_i)}{n-1}} \end{cases} \tag{2}$$

The measured data is substituted into equations (1) and (2), respectively, and the miss distances for point estimation and circumferential estimation are calculated. At this time, the smaller the circle probability deviation and the point estimation value, the better the anti-interference performance of the missile guidance control system. The round probability CEP worth the size can characterize the anti-jamming performance of the missile guidance control system. Since the guidance accuracy index of the anti-tank missile is 1 meter, when the guidance precision of the subsystem is greater than 1 meter, the system is unqualified.

Summary: With the development of science and technology and the credibility of semi-physical simulation technology, the experimental identification technology of weapons and equipment is also developing rapidly. Based on the analysis of the anti-tank missile guidance control system, the semi-physical real-time simulation technology is used to study the performance test indicators and test methods of the anti-tank missile guidance system, which provides a reference for the sub-system test before the missile weapon system identification and acceptance.

References

[1] Fu Ruozhen, Song Zhihuan. Research Status and Prospects of Control System Performance Evaluation [J]. Journal of Huazhong University of Science and Technology(Natural Science Edition), 2009, 1

[2] Ni Hanchang. Research on Anti-jamming Evaluation Simulation Test Technology of Flying Missile[J]. Flying Missile, 2001(9): 45-51

[3] Run Wenxing. Analysis and Simulation of Air-to-ground Missile Guidance Accuracy[J]. Journal of Projectiles, Rockets and Guidance, 2011(25): 833-835

[4] Ying Gaofeng. Study on aging characteristics of silicon rubber corona based on orthogonal test method [M]. Beijing: North China Electric Power University

[5] Zhang Jingnan. Analysis and Simulation of Guidance Accuracy in Cruise Missiles[J]. Aviation Weapons, 2007(1): 25-28

[6] Arthur V, Gerrit M. Missile Avoidance Maneuveres with Simultaneous Decoy Deployment [C] Guidance, Navigation , and Control Conference. Chicago: AIAA, 2009: 1-7

[7] T Takehira. Analytical solution of missile terminal guidance [J]. Journal of Guidance Control and Dynamics, 1998, 21(2): 342- 348

[8] Aidala V J, Hammel S E.Utilization of Modified Polar Coordinates for Bearings-Only Tracking [J]. Transactions on Automatic Control, 1983, 28(3): 283-294

[9] Liu Lin. Evaluation and Confirmation Method of Modern Flight Control System [M]. Beijing: National Defence Industry Press, 2010

[10] Zhao Wendong. Semi-physical simulation of anti-tank missile guidance and control system [J].Journal of Mechanical Engineering University.2015.08:54-58

[11] Zhang Jinyuan. Research on simulation model verification method and tool based on data consistency analysis [D]. Harbin Institute of Technology, 2011.06