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The Design and Implementation of Simulation System about Interior Ballistics of Gas-ejection

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Abstract. In view of the numerical calculation of zero-dimensional interior ballistics is not efficient for catapult interior ballistic engineers and it is difficult to simulate the flow field in the two-dimensional interior ballistic numerical simulation, combining with computer simulation technology, we build a gas-ejection interior ballistic simulation platform according to the idea of system structure. In this platform, the numerical simulation of gas-ejection interior trajectory is carried out from zero-dimensional and two-dimensional interior trajectory mathematical model. The simulation of interior ballistic flow field is accomplished by fluid mechanics software, and output the images of the interior trajectory characteristic parameter curve and temperature, velocity and pressure field. To help engineers to study the impact of structure parameters, material parameters and environmental coefficients on missile ejection. Through the use of military unit testing, the platform has been validated.

Keywords: interior trajectory, zero-dimensional, two-dimensional, numerical simulation

1. Introduction

A missile that strikes a hostile target at a predetermined heading is called an ejection missile[1],[2][7]. Ballistic missiles are divided into strategic and tactical ballistic missiles, solid propellants and liquid propellant ballistic missiles, intercontinental, long-range, medium-range and short-range ballistic missiles according to different classification methods. Catapult missile launch is an external force to the missile fired from the launcher tube, the missile reached a certain height and then fired the engine's. For the study of gas-ejection trajectory, the main methods currently used are theoretical analysis, numerical simulation and experimental study. The theoretical analysis is the zero-dimensional interior ballistic mathematical simulation described in this paper, but the pure mathematical calculation lacks certain supportiveness and can't describe the details of gas flow field in gas-ejection trajectory. Of course, experimental research is the most effective and realistic research method. It requires constant adjustment of gunpowder parameters, functional parameters, etc. to conduct a number of live-fire launches in order to determine the approximate relevant parameters so as to formulate a relatively optimized launch plan, however, the disadvantage is that it consumes a lot of manpower and resources and is less efficient, so it isn't a realistic method. The United States has always been in a monopoly position in the production of catapults. Catapults loaded on aircraft carriers such as France and Brazil are also equipped by the introduction of U.S. technology[3],[5][8]. Based on the current catapults performance bulky, heavy weight, low energy utilization and other defects, on the basis of fully understanding the launching principle and structure of catapult, it is very important to design and analyze the parameters of catapult[9]. Due to the inability to pass large amounts of experiments in China at present, it is an effective measure to study the relevant characteristics of catapults in practical application by using numerical simulation.

A lot of work has been done in numerical simulation of catapult interior trajectory in China, such as Aerospace Institute in Northwestern Polytechnical University, Nanjing University of Science and Technology, Zhengzhou Institute of Mechanical and Electrical Engineering and so on, however, the realization of the gas-ejection trajectory simulation system is quite scarce. Taking the self-projectile catapult as an example, Tan Dacheng built a two-dimensional interior ballistic model of the launcher tube and calculated the interior ballistic performance. Comparing the two-dimensional model and the zero-dimensional model, the results showed that there was little difference between the two models[10]. In terms of the amount of calculation and calculation speed, the zero-dimensional model has a small calculation amount, a fast calculation speed, a large amount of calculation and a long time-consuming in the two-dimensional model. WeiHua Hui, etc. based on the mass conservation, conservation of energy, equations of motion, equation of state and considered various resistance who belongs to the Key Laboratory of Thermal Structure and Internal Flow Field of Northwestern

Polytechnical University, and they constructed the interior ballistic equations[5].At the same time, the interior ballistic simulation system of the projectile surface separation gas- ejection was established.

In this paper, the gas catapult is the research object. In order to study the characteristics of the interior trajectory during the ejection of the projectile missile, such as the pressure of the high pressure chamber, the pressure of the ejector, the temperature of the ejector, etc. Based on the zero-dimensional and two-dimensional interior ballistic mathematical model, we combined the gas-ejection interior ballistic numerical simulation with the computer simulation technology, using the C # language to develop the visual interface. By changing the relevant parameters of the high-pressure chamber and the launcher tube, it can output pressure curve of the high-pressure chamber, the launcher tube temperature's curve etc. The simulation results of the two-dimensional and two-dimensional interior ballistic models were compared with the experimental results to verify the practicality of the gas-ejection interior ballistic simulation platform. The simulation results are real enough to predict and evaluate the accuracy of the missile's interior ballistic, and it has a certain guiding significance for the interior ballistic design. Finally, it will provide decision support for the typical missile launching system plan.

2. Overall design of system

The gas-ejection interior ballistic simulation system provides a development environment for missile launch designers, which is a good interactive, open and extendible environment. Designers are able to use visual interface to set up the interior ballistic parameters of zero-dimensional mathematical models and build the meshes and initial boundary of two-dimensional interior ballistic. The designers conduct theoretical calculations and simulation evaluations of interior ballistic characteristics by this system.

This system consists of two modules that are theoretical calculations and simulation evaluations about interior ballistic. Besides, the theoretical calculation contains two independent parts, which are the classic and the extrapolation interior ballistic model calculation[11-错误!未找到引用源。. The difference is whether the high-pressure gas generator is calculated or not. The former set up many parameters to calculate the pressure of high-pressure chamber, including the powder parameters, physical parameters and so on. The pressure result is the prerequisite of launcher tube calculation, but the latter part of the extrapolation use external data about high-pressure chamber to calculate the launcher tube. The two calculation methods mentioned above, the results of simulation are curves of average pressure, average temperature in launcher tube, missile movement distance and so on. Furthermore, according to the different entrance conditions, the simulation evaluations about interior ballistic have two parts of parameterized simulation and extrapolation simulation. The part of parameterized simulation's pressure entrance conditions are to set up related parameters about nozzle, besides, the pressure and temperature curve obtained by the experiment are imported into the simulation module with the external files in simulation of extrapolation's part, simulation system use it for entrance condition to calculate interior ballistics[11-15].The structure of the simulation system about interior ballistics of gas-ejection as shown in Fig.1.Engineering staff utilize the system of simulation to gain the results of pressure, temperature and gas velocity in launcher tube through two modules. By comparing these results synthetically, the parameters are constantly updated in the simulation system to obtain the optimal parameters settings, which can be applied to a missile launching. This method improves the engineering efficiency and reduces the manpower and material consumption caused by the actual experiment 错误!未找到引用源。].