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Changing law of launching pitching angular velocity of rotating missile

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Abstract In order to provide accurate launching pitching angular velocity (LPAV) for the exterior trajectory optimization design, multi-flexible body dynamics (MFBD) technology is presented to study the changing law of LPAV of the rotating missile based on spiral guideway. An MFBD virtual prototype model of the rotating missile launching system is built using multi-body dynamics modeling technology based on the built flexible body models of key components and the special force model. The built model is verified with the frequency spectrum analysis. With the flexible body contact theory and nonlinear theory of MFBD technology, the research is conducted on the influence of a series of factors on LPAV, such as launching angle change, clearance between launching canister and missile, thrust change, thrust eccentricity and mass eccentricity, etc. Through this research, some useful values of the key design parameters which are difficult to be measured in physical tests are obtained. Finally, a simplified mathematical model of the changing law of LPAV is presented through fitting virtual test results using the linear regression method and verified by physical flight tests. The research results have important significance for the exterior trajectory optimization design.

1. Introduction

A rotating missile is a terminal defense weapon with quick reactions, high launching efficiency and simple structure, etc., the main function of which is to intercept and attack sea-skimming flight anti-ship missiles and high-speed aircrafts. The missile has important practical significance to the coastal defense of the South China Sea. When the missile is launched, the empennage seat is used as a support and contact with the side of spiral guideway in the launching canister so that the missile moves along with the spiral guideway to achieve the rotation movement of the missile launching. In the process of launching the rotating missile, its launching pitching angular velocity (LPAV) must be some dispersed and difficult to be determined due to a variety of influencing factors such as launching angle change, clearance between launching canister and missile, thrust change, thrust eccentricity and mass eccentricity, etc.

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LPAV is an important initial parameter in the exterior trajectory design.[1] The past flight test results prove that the improper parameter value would result in large deviation between theoretical and flight test trajectories, and lead to flight test failure eventually. Therefore, the changing law of LPAV has some significance for the exterior trajectory optimization design. In order to find out the changing law of LPAV of the rotating missile and provide an accurate initial parameter for the exterior trajectory design, it is of necessity to make dynamic modeling and simulation of the rotating missile launching process.[2–4] The traditional mathematic modeling method of launching dynamics is very tedious and the built model is largely simplified, therefore it cannot accurately consider the complex collision between the launching canister and the missile, and even the elastic vibration, large deformation and nonlinear vibration of the missile, the launching canister and the rack.[5–7] Multi-rigid body launching dynamics modeling and simulation technology provides an effective solution to the rotating missile development problems, which considers only the complex collision between the launching canister and the missile but the vibration and deformation of the missile body, the launching canister and the rack.[8,9] The past flight test results prove that LPAV from multi-rigid body launching dynamics simulation cannot satisfy the exterior trajectory design requirement. Rigid-flexible coupling launching dynamics modeling and simulation technology based on the Craig-Bampton modal synthesis method considers only the linear elastic deformation of parts, but the collision between flexible bodies, and not even the larger deformation and nonlinear analysis.[10–14] Therefore, multi-flexible body dynamics (MFBD) modeling and simulation technology is presented to solve the above problems.[15] MFBD technology enables designers to simulate the mechanical environment more really at rotating missile launching.

Therefore, in this paper the rotating missile launching system is taken as an example, and its multi-body dynamics model is built based on the MFBD technology using the modal synthesis method and the nodal method. Based on the built model, the research is conducted on the influence of a series of factors on LPAV such as launching angle change, clearance between launching canister and missile, thrust change, thrust eccentricity and mass eccentricity, etc., using the flexible body contact theory and the nonlinear theory of MFBD technology and we obtain some significant values of the key design parameters which are difficult to be measured in physical tests. Finally, a simplified mathematical model of the changing law of LPAV is presented through fitting the virtual test results by means of the linear regression method and is verified by physical flight tests. The research results have important significance for the exterior trajectory optimization design.

2. Components of launching system and analysis of launching process

The spiral guideway launching system is divided into launcher and missile according to its structural feature. The launcher is composed of U-bracket, launching rack and launching canister. The missile is composed of body, bourrelet, folding rudder and folding empennage. Its topological structure is shown in Fig. 1.

In the launching process, the movement relations of the various components are as follows: after the ignition of the engine, the missile is locked by the lock device and does not move. When the thrust increases to a critical value, the lock device unlocks. The side of empennage seat moves along with the spiral guideway in the launching canister in the role of the bourrelet to achieve the rotation movement of the missile launching. The front and back bourrelet detach the spiral guideway respectively, and also the folding rudder and the folding empennage automatically spread, position and lock respectively.

3. MFBD model of launching system

On the basis of building the finite element model of U-bracket, launching rack, launching canister and missile, according to the topological structure of launching system, in the RecurDyn's simulation environment, the MFBD virtual prototype physical mode of the spiral guideway launching system of the rotating missile is built as Fig. 2.

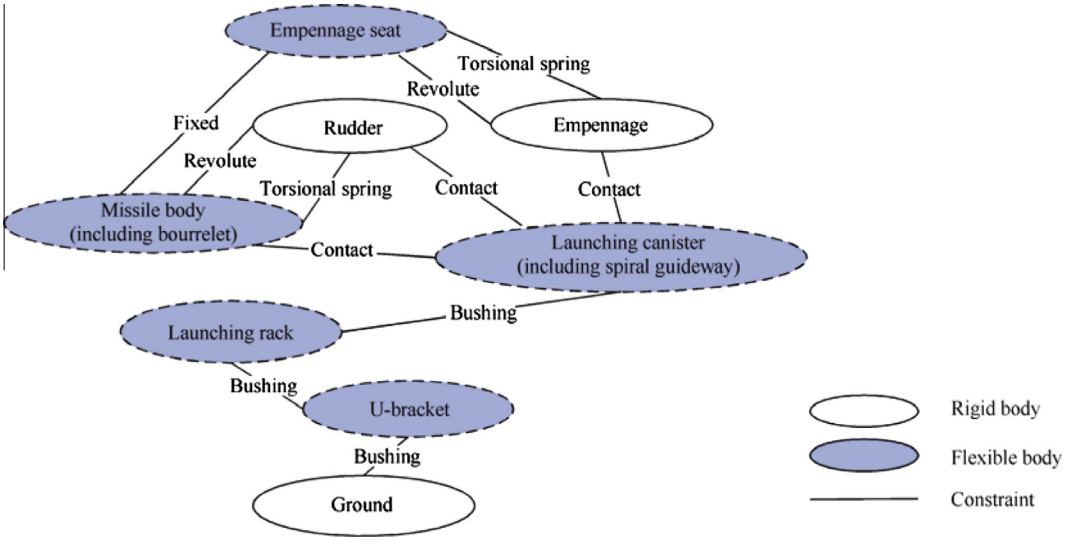

Fig. 1 Topological structure of launching system.