Modeling and Analysis of Standard- 2 Missile Intercepting Flat Flying Target

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Abstract: Firstly, the characteristics of attacking and defending targets in air defense operations are introduced. The model of fire control system and launch zone of ship-to-air missile is described mathematically. The movement analysis of anti-ship missile and ship-to-air missile, the mathematical model of kill zone and launch zone time of missile are established. Finally, the attack and defense models of anti-ship missiles under horizontal flight and dive are established, including anti-ship missile model and standard-2 missile control model. By establishing a mathematical model, we can describe the movement of attack and defense targets with scientific means, and provide a basis for the compilation of simulation programs.

1. Introduction

With the continuous development of high-tech in the military field[1-4], surface warship formation in naval warfare will face great air threats. The development of various precision-guided anti-ship missiles poses great challenges to surface warship defense system. Anti-ship missile defense system has become one of the difficult and hot issues in current research. In order to cope with the increasing threat of anti-ship missile to single ship and fleet, we need to know the attack process of anti-ship missile and the anti-missile process of anti-air missile urgently[5-9]. As a simple and efficient research method, computer simulation makes it possible for us to study it in theory.

2. Flat Flight Target Model

There are two main tasks for the fire control system of ship-to-air missile: one is to take on the air defense of the ship itself, the other is to take on the air defense task of the formation. Because most of the anti-ship missiles fly in the ultra-low altitude attitude, and the detection distance of the radar equipped with modern warships to the anti-ship missiles is generally within 25 kilometers, the guidance system of the anti-ship missile has been working, and the missile will fly to the captured warships under the guidance of the terminal guidance system. Therefore, it can be considered that the anti-ship missile is attacking. The shortcut to the target ship is zero.

According to the model of target motion, we assume that the flying attitude of the future target is super-low altitude and slightly horizontal flight, i.e. the elevation angle of the incoming target, the flying altitude of the incoming target and the acceleration of its kinematics parameter are assumed to be

$$a_m = \begin{bmatrix} a_{mx} \\ a_{my} \\ a_{mz} \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix} \tag{1}$$

In the shooting coordinate system, the velocity relationship of the incoming target is expressed as follows:

$$V_m = \begin{bmatrix} V_{mx} \\ V_{my} \\ V_{mz} \end{bmatrix} = \begin{bmatrix} V_{mx} + V_{mx}^{'} dt \\ V_{my} + V_{my}^{'} dt \\ V_{mz} + V_{mz}^{'} dt \end{bmatrix} \tag{2}$$

The displacement relation expression of the incoming target in the shooting coordinate system is as follows:

$$\begin{cases} S_{mx} = S_{mx} + S_{mx}^{'} dt \\ S_{my} = S_{my} + S_{my}^{'} dt \\ S_{mz} = S_{mz} + S_{mz}^{'} dt \end{cases} \tag{3}$$

3. Control Model of Standard-2 Missile

3.1 Initial Velocity Control Model of Standard-2 Missile

After launching, the missile controls its speed by setting the command acceleration. In the speed control model, the command acceleration given by the computer is set to be a_x, a_y, a_z, and the real acceleration of the missile is a_{xr}, a_{yr}, a_{zr}. Fig. 1 shows the relationship between the command acceleration and the real acceleration of each axis, respectively.

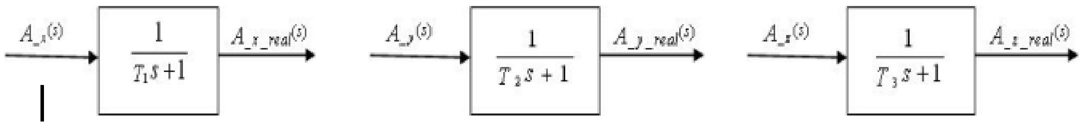

Figure 1 Transfer Function Diagram of Instruction Acceleration Control

After calculation, we can get the true acceleration of the missile as follows:

$$a_r = \begin{bmatrix} a_{xr} \\ a_{yr} \\ a_{zr} \end{bmatrix} = \begin{bmatrix} a_{xr} + a_{xr}^{'} dtr \\ a_{yr} + a_{yr}^{'} dtr \\ a_{zr} + a_{zr}^{'} dtr \end{bmatrix} \tag{4}$$

Where

$$\begin{bmatrix} a_{xr}^{'} \\ a_{yr}^{'} \\ a_{zr}^{'} \end{bmatrix} = \begin{bmatrix} (a_x - a_{xr})/0.01 \\ (a_y - a_{yr})/0.6 \\ (a_y - a_{yr})/0.6 \end{bmatrix} \tag{5}$$

In the firing coordinate system, the velocity relationship of ship-to-air missile is expressed as follows:

$$V_s = \begin{bmatrix} V_{sx} \\ V_{sy} \\ V_{sz} \end{bmatrix} = \begin{bmatrix} V_{sx} + a_{xr} dt \\ V_{sy} + a_{yr} dt \\ V_{sz} + a_{zr} dt \end{bmatrix} \tag{6}$$

The displacement relation of ship-to-air missile in firing coordinate system is expressed as follows:

$$\begin{cases} S_{sx} = S_{sx} + V_{sx} dt \\ S_{sy} = S_{sy} + V_{sx} dt \\ S_{sz} = S_{sz} + V_{sx} dt \end{cases} \tag{7}$$

4. Vertical Acceleration Stage Control Model of Standard-2 Missile

After launching the missile, we define the process before the set time T of the missile flight as the vertical acceleration stage of the missile. In this model, the vertical acceleration time T = 10s is taken. In order to simplify the model, it is assumed that the missile will be provided with a certain tilt acceleration a_pitch by the system after launching, which is used to change the missile's motion in the plane yOz. As shown in Figure 2.

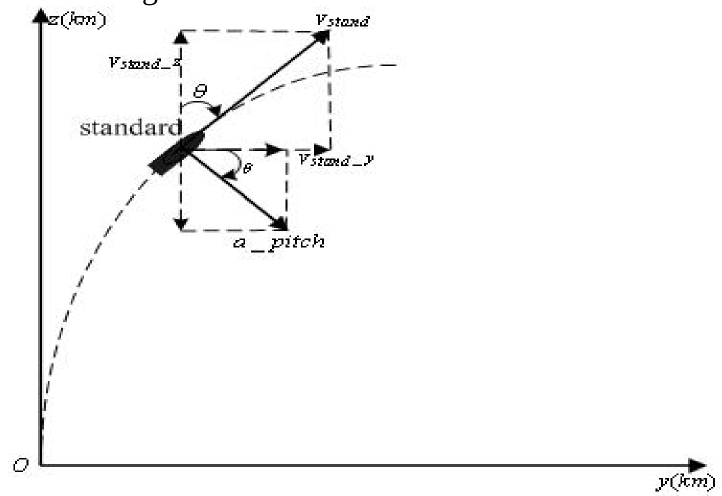

Figure 2 Vertical Acceleration Stage Model of Standard-2 Missile

The direction of a_p is perpendicular to the velocity direction of the missile at any time during the vertical acceleration phase and points to the bending direction of the trajectory. In order to facilitate the simulation of different situations in the follow-up process, a_p is set as a number controlled by variable parameters, that is, $a_p = K*(1-e\wedge(-0.5*(t)))$, and K are set to be variable.

In the vertical acceleration phase, the command acceleration of the system is set as follows:

$$\begin{bmatrix} a\_x \\ a\_y \\ a\_z \end{bmatrix} = \begin{bmatrix} 0 \\ 340*3/t \\ 0 \end{bmatrix} \tag{8}$$

Among them, t_stand is the timing of the missile starts with the firing point as the benchmark. We can get the actual acceleration of the missile in flight as follows:

$$\begin{cases} a_x = a_{px} \\ a_y = a_{px} + 340*3.5/t \\ a_z = 0 \end{cases} \tag{9}$$

5. Conclusion

On the basis of the target model and the anti-ship missile model, the anti-ship missile attack and defense model under the condition of flat flight and dive is established, including the anti-ship missile model and the standard-2 missile control model. Through the establishment of mathematical model, it lays a foundation for the interception simulation of different flying targets by modifying the parameters.

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