Modeling and Simulation Analysis of a Kind of High Speed Aircraft

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Abstract. High speed aircraft is researched widely by researchers because of its high value of application in the weapon design and military purpose. The modeling and simulation of high speed model is research and the open loop response is researched. At last, detailed numerical simulation was done with a real simplified pitch channel system model to testify the ability of aircraft body.

Introduction

There are three main advantages of hypersonic vehicles: first, they can fly fast and hit any global target in two hours if they are used for military purposes [1-3]; and second, they can fly from Beijing to New York in less than two hours if they are used for civilian purposes. Second, it is difficult to detect and penetrate. Because of the high speed and short passage time of hypersonic aircraft, the cumulative echoes of defensive radar are less [4-6], which makes it difficult to detect. Even if found, the ground air defense weapon system is difficult to achieve effective targeting, so the penetration probability is very high. Thirdly, the hypersonic missile with long range and great power is currently being studied, and its range is hundreds or even thousands of kilometers.

The research of super vehicle model [7-14] makes the research of super vehicle more convenient. Model research can also reflect the performance indicators of aircraft very well. For researchers, through a series of experimental data, theoretical deduction and modeling, the original model and coefficients can be obtained. On this basis, it is more conducive to model research and analysis.

Digital-Analog Description and Its Open-Loop Response

In this chapter, based on a simplified hypersonic model of pitch channel, the resistance is related to the quadratic of moment and angle of attack, and the relationship is linear. At the same time, the hinge of velocity is smaller. The open-loop response of the hypersonic model is studied without considering the effect of elastic modal deformation, so as to understand the dynamic characteristics of the hypersonic model preliminarily.

Based on the super model of Zhou Chuan of Nanjing University of Technology and Jiang Bin of Nanjing University of Aeronautics, this paper analyses the pitch channel model of super aircraft.

Firstly, the longitudinal simplified equation of motion is as follows:

$$\dot{V} = \frac{T\cos\alpha - D}{m} - g\sin\gamma \tag{1}$$

$$\dot{\gamma} = \frac{L + T\sin\alpha}{mV} - \frac{g\cos\gamma}{V} \tag{2}$$

$$\dot{\alpha} = q - \dot{\gamma} \tag{3}$$

$$\dot{q} = \frac{M}{I} \tag{4}$$

$$\dot{h} = V\sin\gamma \tag{5}$$

Equation description: lift, drag, thrust, *M*: pitch moment of aircraft, *V*: flight speed of aircraft. The lift *L*, drag *D* and *T* thrust are respectively:

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$$L = \overline{q}SC_L \tag{6}$$

$$D = \overline{q}SC_D \tag{7}$$

$$T = \overline{q}SC_T \tag{8}$$

The formulas are lift coefficient, drag coefficient and thrust coefficient, respectively; *S*: characteristic area of aircraft.

The concrete expressions are as follows:

$$C_L = C_L^{\alpha}\alpha + C_L^{\delta}\delta + C_L^0 \tag{9}$$

$$C_D = C_d^{\alpha^2}\alpha^2 + C_D^{\alpha}\alpha + C_D^{\delta^2}\delta^2 + C_D^{\delta}\delta + C_D^0 \tag{10}$$

$$M = \overline{q}S\overline{c}[C_{M\alpha} + C_{M\delta} + C_{Mq}] \tag{11}$$

$$C_{M\alpha} = C_{M\alpha}^{\alpha^2}\alpha^2 + C_{M\alpha}^{\alpha}\alpha + C_{M\alpha}^0 \tag{12}$$

$$C_{M\delta} = c_e(\delta_e - \alpha) \tag{13}$$

$$C_{M\alpha} = 10^{-4}(0.06 - e^{-M_a/3})(-2\alpha^2 + 120\alpha - 1)$$

$$C_{Mq} = \frac{\overline{c}q}{2V}(-0.025M_a + 1.37)(-0.0021\alpha^2 + 0.0053\alpha - 0.23) \tag{14}$$

$$C_{M\delta} = 0.0292(\delta - \alpha)$$

$$C_L = \alpha(0.493 + 1.91/M_a) \tag{15}$$

$$C_D = 0.0082(171\alpha^2 + 1.15\alpha + 2)(0.0012M_a^2 - 0.054M_a + 1) \tag{16}$$

$$C_T = \begin{cases} 38[1 - 164(\alpha - \alpha_0)^2](1 + 17/M_a)(1 + 0.15)\eta, \eta < 1 \\ 38[1 - 164(\alpha - \alpha_0)^2](1 + 17/M_a)(1 + 0.15\eta), \eta < 1 \end{cases} \tag{17}$$

The parameters of the above expression are introduced as follows: *L* is lift, *D* is drag, *T* is thrust, *h* is altitude of missile system.

Open-Loop Response Simulation Results

Firstly, in order to analyze the simulation results conveniently, we need to make sure that the fuel consumption of the aircraft in a short time has no effect on the quality of the aircraft, the total mass and the mass layout of the aircraft remain unchanged, so that the rotational inertia of the hypersonic vehicle will not be affected at this time, and the elastic deformation will not occur at the same time, so as to facilitate the analysis of the simulation results of the model.

Set the model parameters as follows:

$$I_{xx} = -7.1*10^{-5}m^2 + 19.1m - 59430$$

$$I_{yy} = -8.03*10^{-4}m^2 + 219.74m - 1690000$$

$$I_{zz} = -8.03*10^{-4}m^2 + 219.74m - 1690000$$

$$I_{yy0} = 1.23*10^7,\ v_s = 3.017*10^2,\ \rho_a = 1.84*10^2$$

$$g_a = 9.7147,\ h = 30000,\ V = 4525,\ \eta_c = 0.15662$$

Set the initial value of actuator is zero, and the simulation result is shown as following figures.

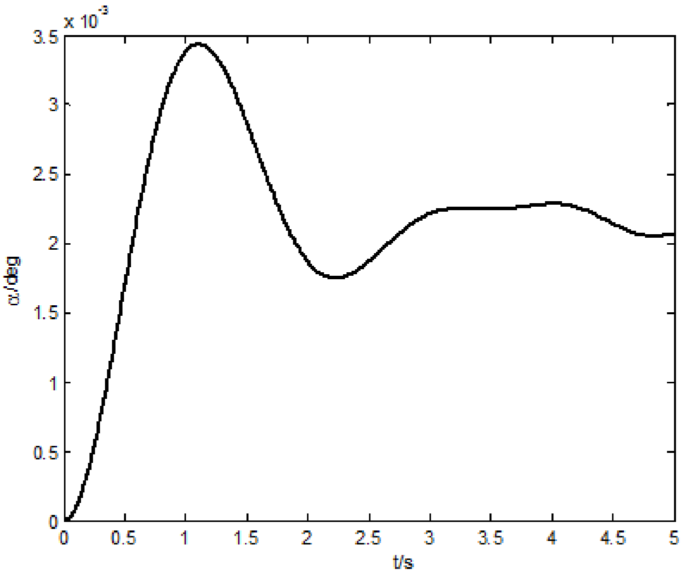

Figure 1 The curve of attack angle

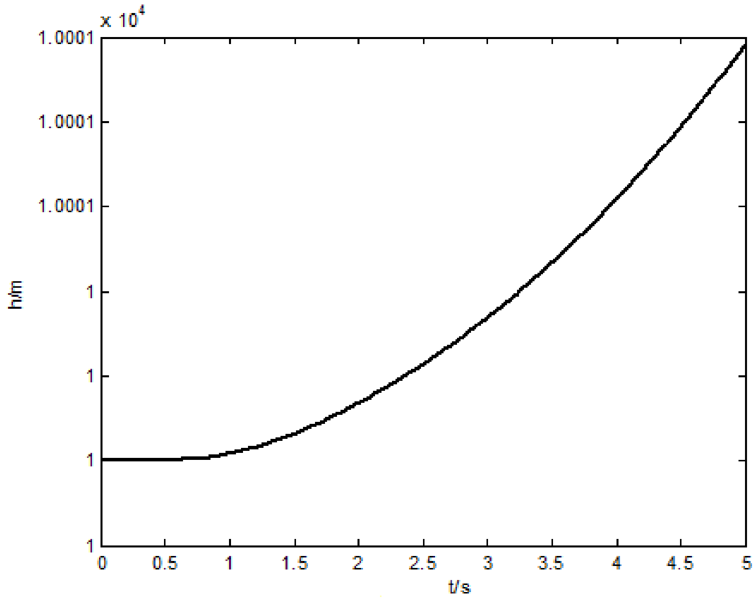

Figure 2 The curve of height

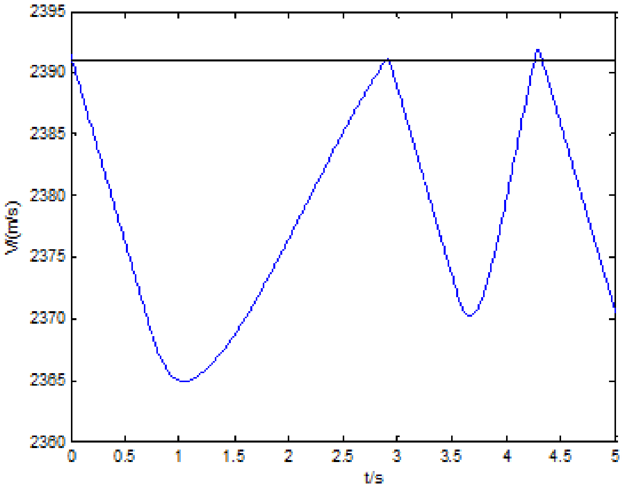

Figure 3 The curve of speed

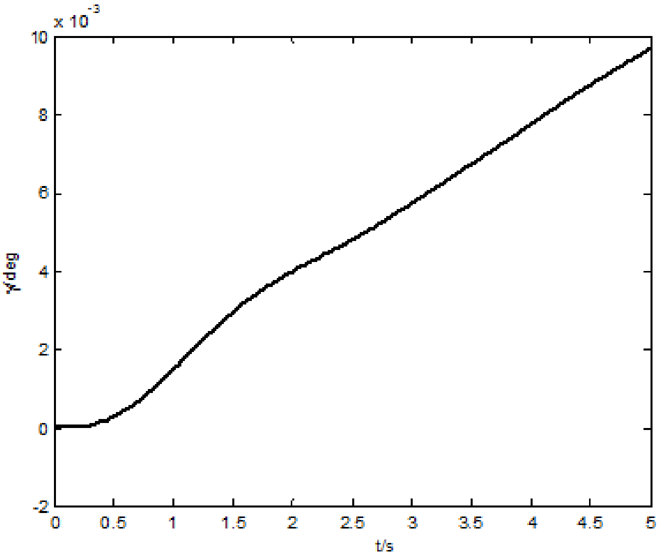

Figure 4 The curve of speed

Conclusions

Through the analysis of the simulation images, it can be seen that the angle of attack of the aircraft during flight is about 2 degrees. Although the overshoot is large at first, it tends to be stable afterwards. At this time, the lift and gravity of the aircraft are balanced, and the altitude of the aircraft is stable at 1000 meters. At the same time, the expected speed of the aircraft is 2391.46 meters per second. It can be seen that the actual speed oscillates between 2365 and 2395. For hypersonic vehicles, the speed control is within the controllable range. The feasibility of the control can be demonstrated by combining the fuel supply factor curve.

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