Research on Improved PID Control Algorithm of a Kind of High Speed Vehicle

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Abstract. According to the nonlinear model of pitch channel of a hypersonic vehicle, the open-loop control is studied, and the response curve is given. On this basis, this paper makes a research on PID control, PID controller design and the introduction of the angular velocity to increase the system damping, which constitutes improved PID control. At the same time, single channel flight simulation is carried out, and the results of digital simulation are given.

Introduction

Since the concept of hypersonic combustion was put forward in 1950s, the research on hypersonic control in the United States and the western countries has lasted for more than half a century. In China, the research of hypersonic aircraft and superb engineering is a key project which has concentrated our much focus. It’s as difficult as the spacecraft and the moon program. And Hypersonic control problem is also a hot and difficult problem in the control field at home and abroad in the last ten years. As academician Huang Lin pointed out, the strong coupling of hypersonic vehicle, classical nonlinear and fast time-varying characteristics have brought great challenges to the control of science .So it is no doubt that the research on the control theory of hypersonic vehicle is of great significance. There are a lot of researches about super hypersonic vehicle, and here we use the model of Zhou Chuan from BIT and Jiang Bin from CZ to carry on the simulation experiment.

Model Description

Considering the elastic shape structure, a kind of pitch channel hypersonic aircraft model built according to Lagrange equation is released by USA air force as followed:

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

$$\dot{\phi} = -2\zeta\omega_n\phi - \omega_n^2\phi + \omega_n^2\phi_c \tag{2}$$

$$\dot{\gamma} = \frac{L + T\sin\alpha}{mV} - \frac{g\cos\gamma}{V} \tag{3}$$

$$\dot{\alpha} = q - \dot{\gamma} \tag{4}$$

$$\dot{q} = \frac{M}{I} \tag{5}$$

$$\dot{h} = V\sin\gamma \tag{6}$$

$$\ddot{\eta}_i = -2\varepsilon_m\omega_{mi}\dot{\eta}_i - \omega_{mi}^2\eta_i + N_i \tag{7}$$

Where

$$T = \bar{q}s(C_{T\phi}\phi + C_T + C_T^{\eta}\eta), \quad D = \bar{q}SC_D \tag{8}$$

And V is speed, γ is the speed angle, α is attack angle, Q is the attitude angle speed, h is the height, ϕ is the oil supplying factor, δ_c is the duck wing and δ_e is the lift rudder.

Analysis of Open Loop Response

According to the simulation results of the open-loop response of the hypersonic vehicle, the rudder deflection $\delta_c = 0$ is set, as shown in the Matlab language program:

```
deta=upitch;
deta=0;
```

At this time, the control amount upitch=0, which doesn't work. And the angle of attack simulation images are as follows:

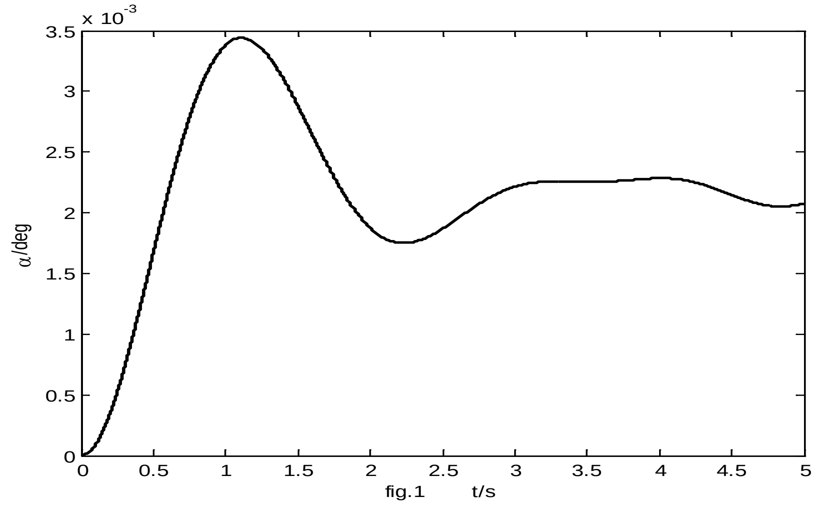

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Fig. 1 Angle of attack curve

It can be seen that the angle of attack simulation image oscillation, but still is able to maintain stability. Next, we will try to add the PID control to improve the performance of the system.

The design of attack angle tracking PID controller and the definition of angle of attack error is as follows:

$$e_\alpha = \alpha - \alpha^d \tag{9}$$

The standard PID controller can be written as follows:

$$u(t) = k_p \left(e(t) + \frac{1}{T_I} \int_0^t e(t)dt + \frac{T_d e(t)}{dt} \right) \tag{10}$$

By introducing angular rate damping, in this paper, the improved PID controller is as follows:

$$u_p = k_p e_\alpha + k_i \int e_\alpha dt + k_d \dot{e}_\alpha + k_q q \tag{11}$$

According to the above formula, the preparation of the Matlab program is as follows:

```
upitch=kp_alfa*ealfa+ks_alfa*sealfa+kd_alfa*dalfa+q*kq;
deta=upitch;
```

Finally, based on the above model, the single channel flight simulation program is established, and the flight simulation curve is obtained as follows:

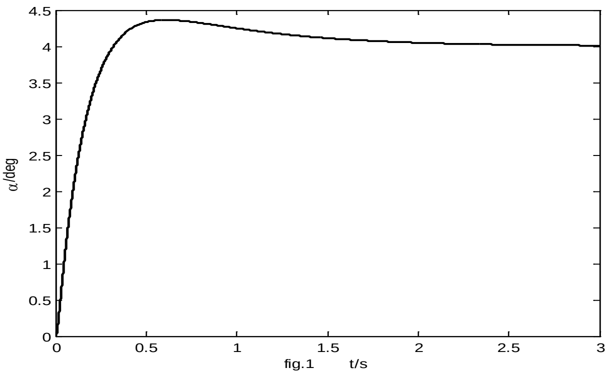

Fig. 2 Angle of attack curve

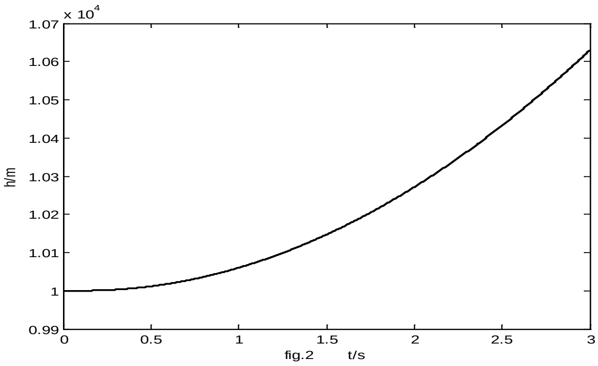

Fig. 3 Height curve

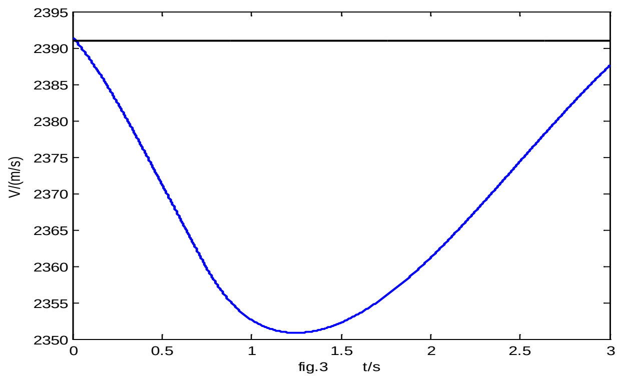

Fig. 4 Velocity curve

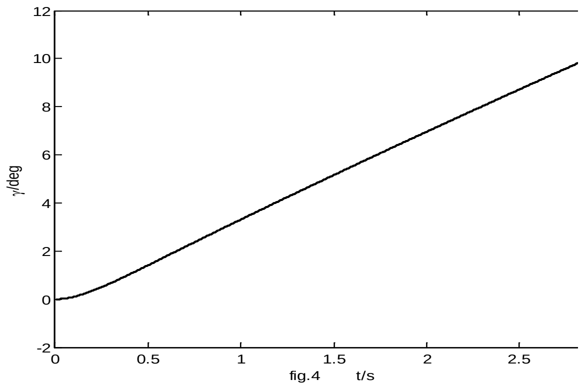

Fig. 5 Speed inclination curve

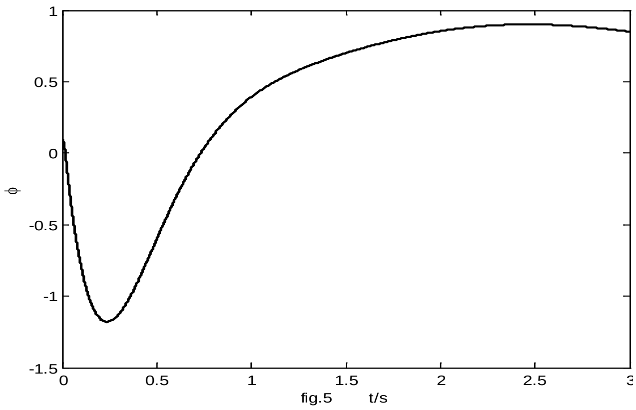

Fig. 6 Fuel supply factor curve

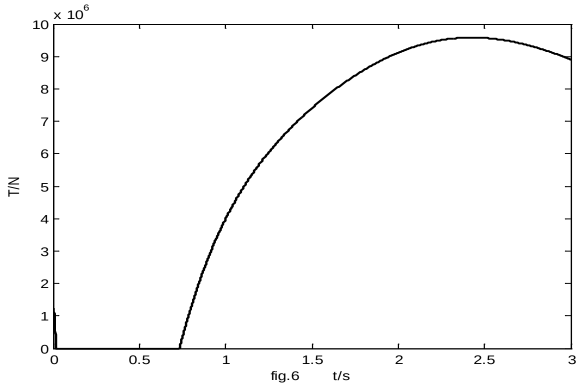

Fig. 7 Thrust curve

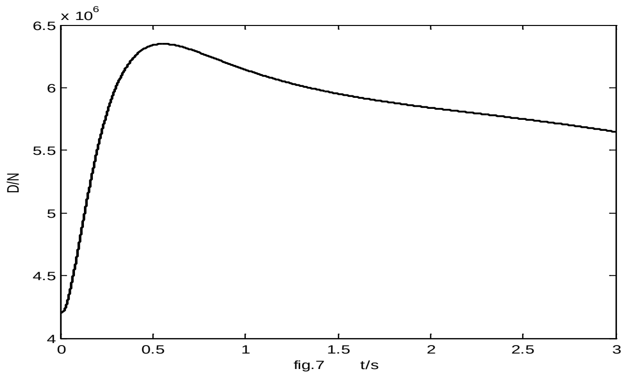

Fig. 8 Resistance curve

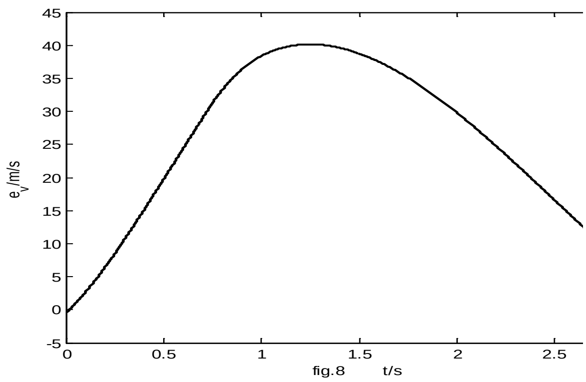

Fig. 9 Velocity error curve

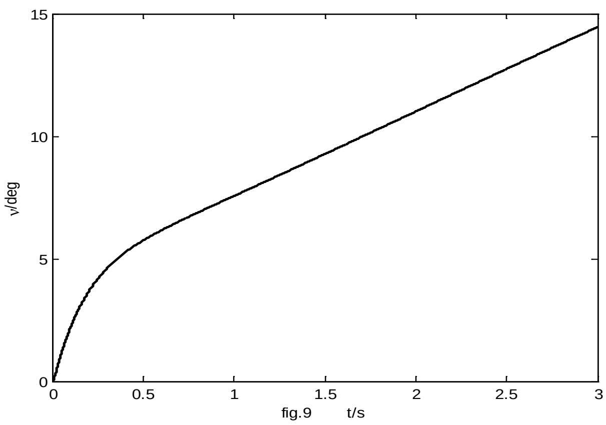

Fig. 10 Attitude angle curve

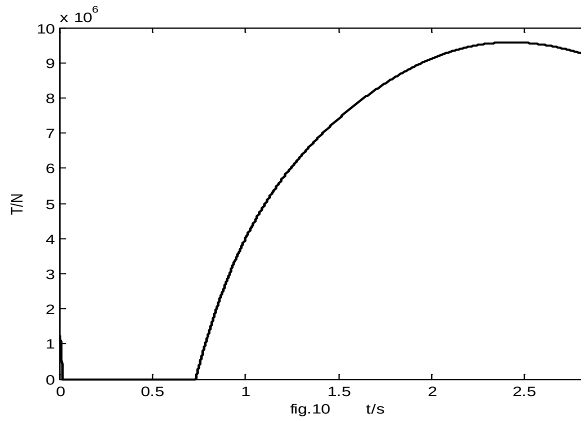

Fig. 11 Lift curve

From the several procedures and simulation curves above, We can see that under the action of the angle of attack tracking PID controller, angle of attack tends to be stable and in over damping state without overshoot. But without control it has overshoot in less damping state .At this time, the velocity and attitude angle are both in the slope response state, that is, uniform speed increases. And the height is in a rapid climb in the state, which climbs 450 meters in about 2.5 seconds. Overall, the open-loop model is relatively stable and similar to the general supersonic missile.

Conclusions

According to the nonlinear model of pitch channel of a hypersonic vehicle, in this paper, a class of improved PID controller is constructed to improve the stability of hypersonic vehicle by introducing the angle of attack and the pitch angle rate, which increases the system damping. And the digital simulation verifies the correctness and validity of this method.

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