Modeling and PID Control of Height Loop of a Kind of Airship Vehicle

Yidong Wang[1,a], Junwei Lei[2, b] and Lingling Wang[2,c]

[1]the 91872th unit of PLA, Beijing, China

[2]Department of control engineering, Naval aeronautical and astronautical University

Yanti, 264001

[a]wangyidong96107@163.com, [b]leijunwei@126.com

Keywords: airship; pitch channel; adaptive; PID; stability

Abstract. The airship modeling is the basic of the airship control problem. Based on airship modeling of pitching channel of airship and its nonlinear model, an traditional PID altitude controller of airship is designed. Finally, this control method is proved to be effective by numerical simulation.

Introduction

From the point of view of foreign application, airship is used as a platform of the early warning and surveillance system. Toshitaka pointed out that stratosphere is very good for airship hovering, because stratosphere is stable[1-3]. So airship become more popular as a relay station communication or monitoring platform. For the above reason, this paper has studied the nonlinear model of pitching channel of stratosphere airship.

The airship modeling is the basic of the airship control problem. And PID control method is a popular method, the PID control method is simple and mature. Based on airship nonlinear model of pitching channel, this paper has studied the PID control of loop of height, and this studies are useful to the further design of airship[4-5].

Model Description

Based on the previous work, the pitch channel model of airship can be described as follows:

$$M\dot{x} = f(x) + g(x)u \tag{1}$$

And $x = [u \quad w \quad q \quad \theta \quad x \quad z]$, M satisfies

$$M^{-1} = \begin{bmatrix} a_{11} & & a_{13} & & & \\ & a_{22} & & & & \\ a_{31} & & a_{33} & & & \\ & & & 1 & & \\ & & & & 1 & \\ & & & & & 1 \end{bmatrix} \tag{2}$$

The definition of a_{ij} see the definition of M in previous work.

Choose the expect value of all states u, w, q, θ, x, z are $u^d, w^d, q^d, \theta^d, x^d, z^d$,Define the error variable $e = x - x^d$, $\dot{e} = \dot{x}$, then it hold[6-7]

$$M\dot{e} = f(x) + g(x)u \tag{3}$$

Use the inverse matrix of M

$$\dot{e} = M^{-1} f(x) + M^{-1} g(x)u \tag{4}$$

To make it convenient for reading, some functions can be written as follows

$$f(x) = \begin{bmatrix} f_1 \\ f_2 \\ f_3 \\ f_4 \\ f_5 \\ f_6 \end{bmatrix} \quad u = \begin{bmatrix} u_1 & u_2 \end{bmatrix}^T \tag{5}$$

where

$$\begin{bmatrix} f_1 \\ f_2 \\ f_3 \\ f_4 \\ f_5 \\ f_6 \end{bmatrix} = \begin{bmatrix} -(m+m_{33})wq + Q[C_{X1}\cos^2\alpha + C_{X2}\sin(2\alpha)\sin(\alpha/2) \\ (m+m_{11})qu + ma_z q^2 + Q[C_{z1}\cos(\alpha/2)\sin(2\alpha) + C_{z2}\sin(2\alpha) + C_{z3}\sin(\alpha)\sin(|\alpha|)] \\ -ma_z wq(-rv) + Q[C_{M1}\cos(\alpha/2)\sin(2\alpha) + C_{M2}\sin(2\alpha) + C_{M3}\sin(\alpha)\sin(|\alpha|)] - a_z \sin\theta W \\ q \\ u\cos\theta + w\sin\theta \\ -u\sin\theta + w\cos\theta \end{bmatrix}$$

Define

$$M^{-1}f(x) = \begin{bmatrix} f_{a1} \\ f_{a2} \\ f_{a3} \\ f_{a4} \\ f_{a5} \\ f_{a6} \end{bmatrix} = \begin{bmatrix} a_{11}f_1 + a_{13}f_3 \\ a_{22}f_2 \\ a_{31}f_1 + a_{33}f_3 \\ f_4 \\ f_5 \\ f_6 \end{bmatrix} \tag{6}$$

And

$$g(x)u = \begin{bmatrix} u_2 \\ k_1u_1 \\ k_2u_1 \\ 0 \\ 0 \\ 0 \end{bmatrix} \tag{7}$$

Then the system can be written as follows[8-9]

$$\begin{bmatrix} \dot{u} \\ \dot{w} \\ \dot{q} \\ \dot{\theta} \\ \dot{x} \\ \dot{z} \end{bmatrix} = \begin{bmatrix} f_{a1} \\ f_{a2} \\ f_{a3} \\ f_{a4} \\ f_{a5} \\ f_{a6} \end{bmatrix} + \begin{bmatrix} a_{11}u_2 + a_{13}k_2u_1 \\ a_{22}k_1u_1 \\ a_{31}u_2 + a_{33}k_2u_1 \\ 0 \\ 0 \\ 0 \end{bmatrix} \tag{8}$$

The PID Control Design For Height Control System

Inside loop attitude angle controller ensure airship can follow the tracks of expected angle of pitch, so outside loop altitude controller can control altitude[10].

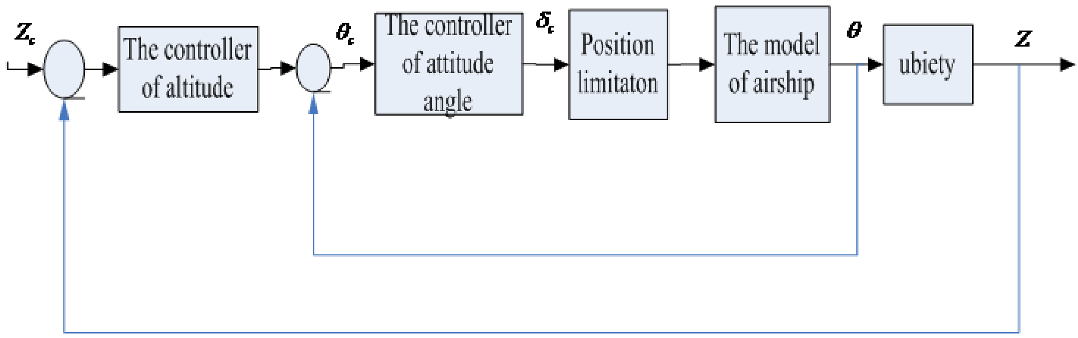

Fig 1 schematic diagram the control loop of altitude

Choose[11-12]

$$K_p = -0.01$$
$$K_i = 0 \qquad (9)$$
$$K_d = -0.1$$

Numerical Simulation

Assume $u = 20\,m/s$, $T_m = 5000N$, initial position $x_e = y_e = z_e = 0$. Other quantity of state is 0, choose $z_d = -100$ [13-15], simulation results are as

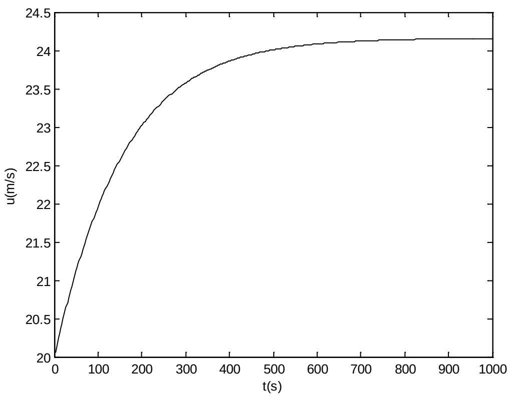

Fig.2 Forward Velocity

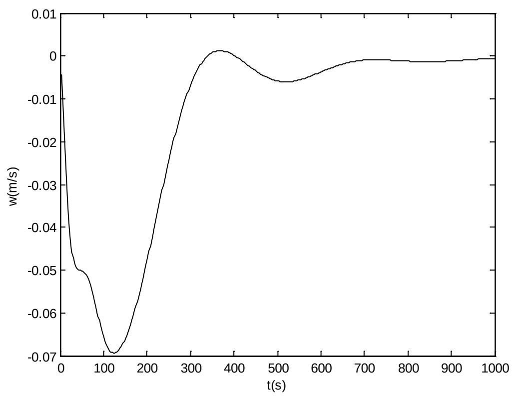

Fig.3 Vertical Velocity

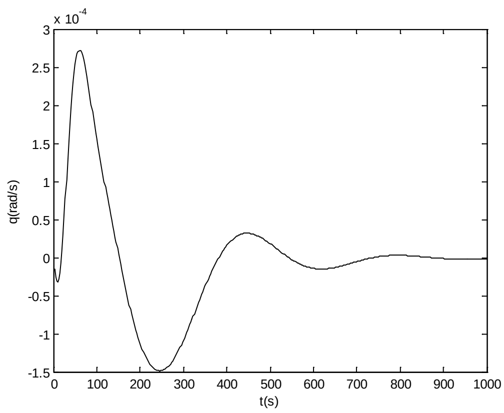

Fig. 4 Angle Velocity

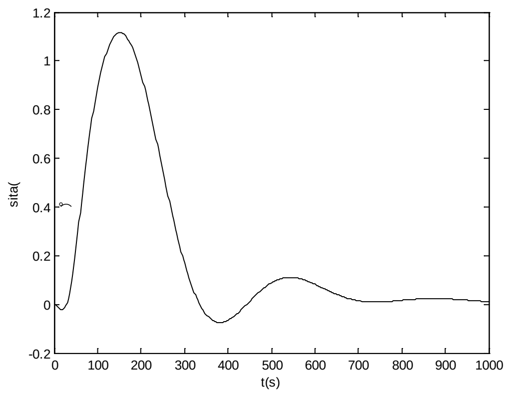

Fig.5 Pitch Angle

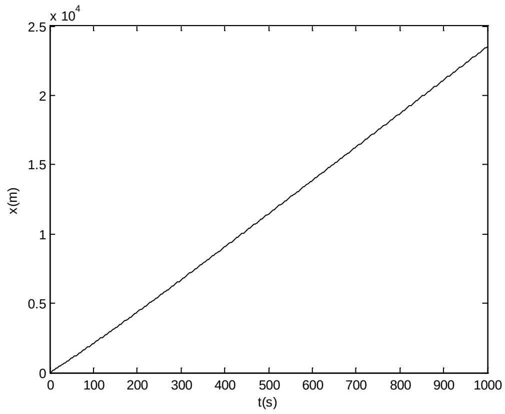

Fig. 6 Flying Distance

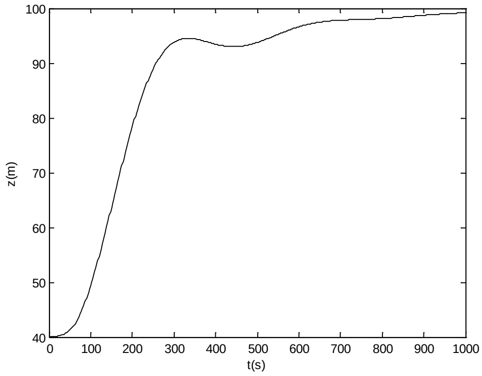

Fig. 7 Height

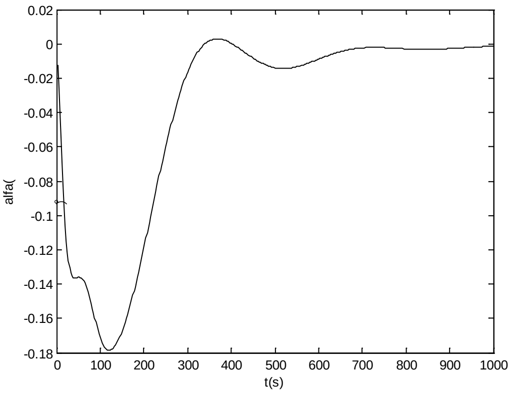

Fig. 8 Pitch Actuator Angle

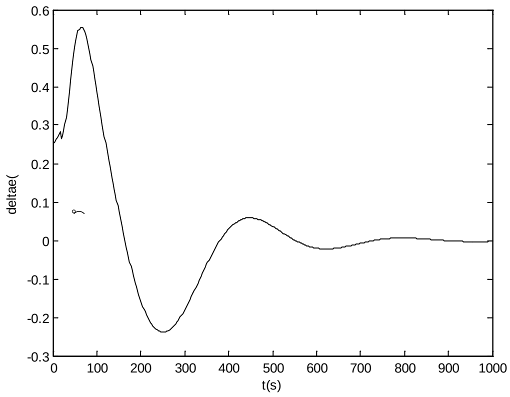

Fig. 9 δ_e

The simulation results show that airship can follow the tracks of expected altitude in a small area, and be stable.

Conclusion

The airship modeling is the basic of the airship control problem. And PID control method is a popular method, the PID control method is simple and mature. Based on airship nonlinear model of pitching channel, this paper has studied the PID control of loop of height, and this studies are useful to the further design of airship.

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