Modeling And PID Control Of A Kind Of Airship Vehicle In Stratosphere

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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 attitude angle controller of airship is designed. Finally, this control method is proved to be effective by numerical simulation.

Introduction

The advantages of airship make airship become more popular in regional high resolution warning, monitoring of territorial, reconfigurable communication, navigational positioning and other fields. Many countries regard airship plan as an important content of the improvement of the efficiency of aero-weapons system, and has studied airship for many years.

In 1998, Brazil AURORA project team of stratospheric airship published initial literature[1]. Literature[2] has given YEZ-2A airship's six degree-of-freedom model that has been confirmed by test flight, and has analysed the part of dynamic response. The course of the flight is divided into five parts including take off, cruise, wheel, suspension and land in literature[3], and corresponding controllers are designed in traditional PID control method.

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.[4-5]

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

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

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

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

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[6-8]

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

The PID Control Design For Attitude Control System

When airship gets disturbed, attitude is the most vulnerable. Attitude control can correct deviation of attitude angle, on the other hand, it can control attitude angle track expected value[9].

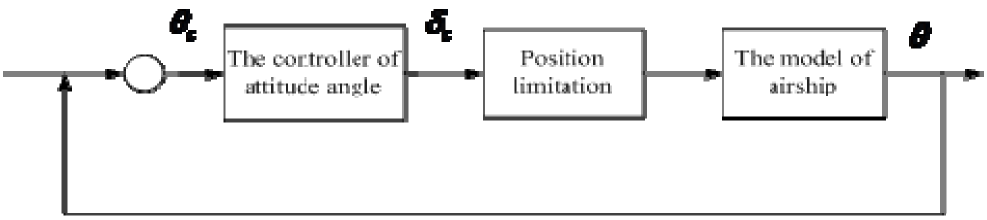

Fig 1 schematic diagram the control loop of attitude angle

Design:

$$\delta_e = K_p\left(\theta_d - \theta\right) + K_i\int_0^t\left(\theta_d - \theta\right)dt + K_d\left[\frac{d\left(\theta_d - \theta\right)}{dt}\right] \tag{8}$$

θ_d is expected angle of pitch[10-11]. choose

$$\begin{aligned} K_p &= 0.25 \\ K_i &= 0.0015 \\ K_d &= 1 \end{aligned} \tag{9}$$

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 $\theta_d = 10°$ [12-13], simulation results are as

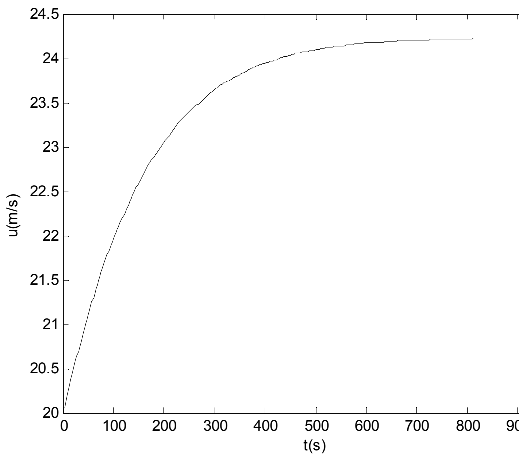

Fig.2 Forward Velocity

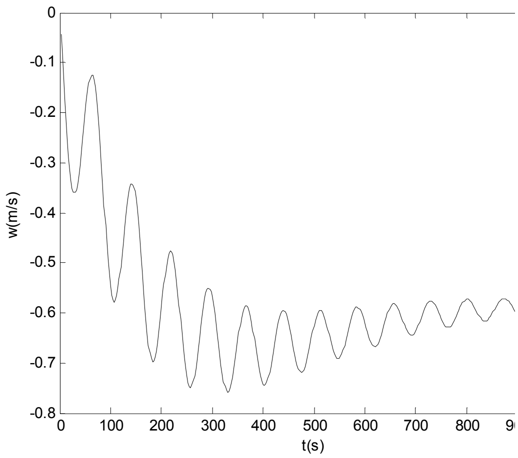

Fig.3 Vertical Velocity

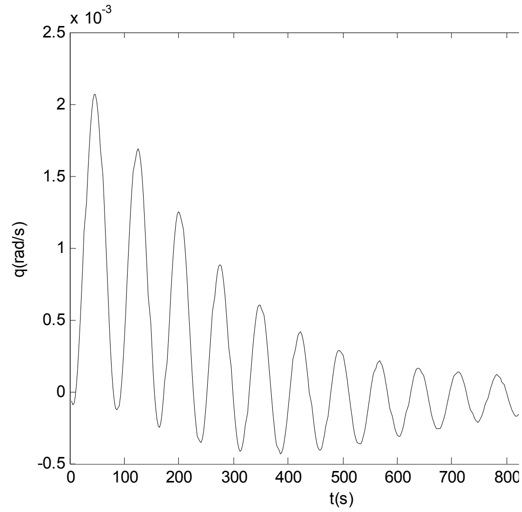

Fig. 4 Angle Velocity

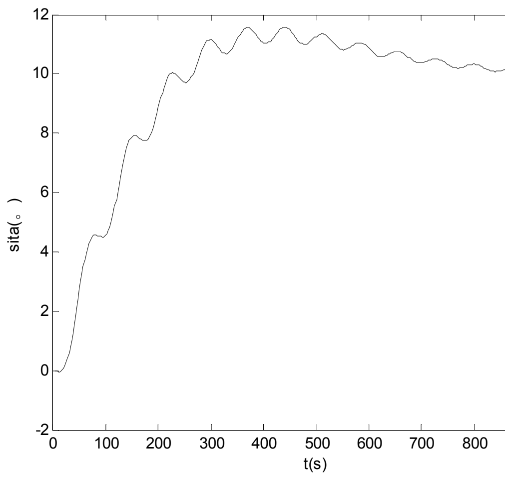

Fig.5 Pitch Angle

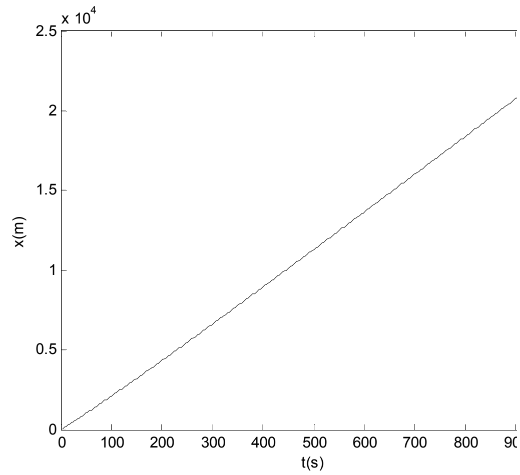

Fig. 6 Flying Distance

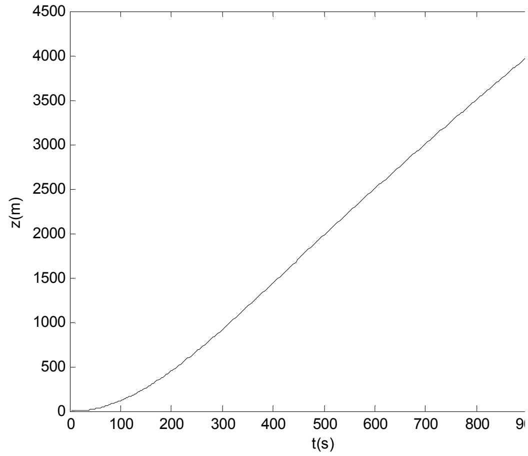

Fig. 7 Height

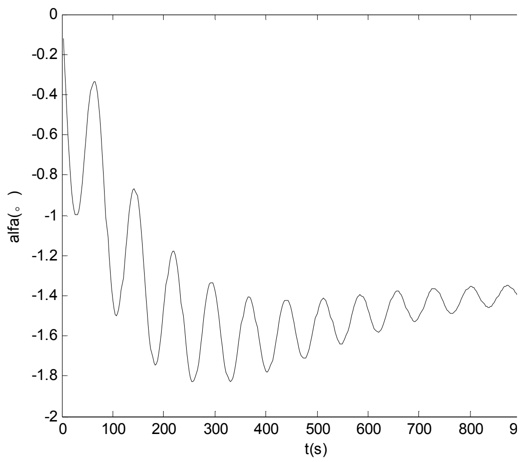

Fig. 8 Pitch Actuator Angle

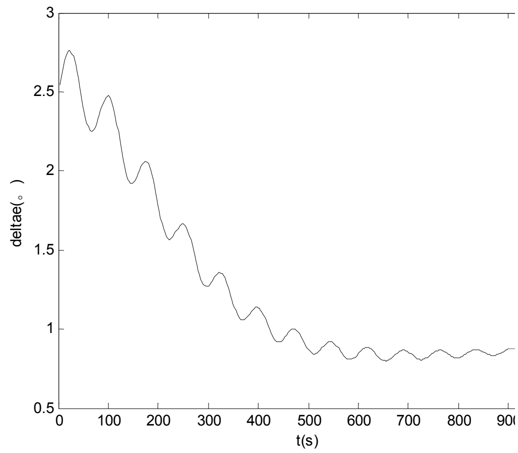

Fig.9 δ_e

The simulation results show that airship can follow the tracks of expected angle of pitch in 1000s, and be stable.

Conclusion

In this paper, a nonlinear model of pitching channel of airship has been established, and this paper has used an traditional PID control scheme to control the angle of pitch of airship. The simulation results show that airship can follow the tracks of expected angle of pitch in 1000s, and be stable.

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