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

Guangbin Wu¹,a, Guoqiang Liang¹,b, Huali Wu¹,c and Junwei Lei¹,d

Department of control engineering, Naval aeronautical and astronautical University, Yanti, 264001
demail: leijunwei@126.com

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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:

\[ M \ddot{x} = f(x) + g(x)u \] (1)

And \[ x = [u \ w \ q \ \theta \ x \ z] \], \( M \) satisfies

\[ M^{-1} = \begin{bmatrix}
    a_{11} & a_{13} \\
    a_{22} & a_{33} \\
    1 & 1 \\
    1 & 1
\end{bmatrix} \] (2)

The definition of \( a_y \) see the definition of \( M \) in previous work.[4-5]

Choose the expect value of all states \( u, w, q, \theta, x, z \) 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

\[ M \dot{e} = f(x) + g(x)u \] (3)

Use the inverse matrix of \( M \)

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

To make it convenient for reading, some functions can be written as follows
\[
    f(x) = \begin{bmatrix} f_1 \\ f_2 \\ f_3 \\ f_4 \\ f_5 \\ f_6 \end{bmatrix} u = [u_1 \ u_2]' 
\]

(5)

where

\[
    f_1 = -(m + m_3)wg + QC_{x1} \cos^2 \alpha + QC_{x2} \sin(2\alpha)\sin(\alpha/2) \\
    f_2 = (m + m_1)q + ma_1 q^2 + QC_{c1} \cos(\alpha/2)\sin(2\alpha) + QC_{c2} \sin(2\alpha) + QC_{c3} \sin(\alpha) \sin[\alpha] \\
    f_3 = -ma_2 wq(-r) + QC_{m1} \cos(\alpha/2)\sin(2\alpha) + QC_{m2} \sin(2\alpha) + QC_{m3} \sin(\alpha) \sin[\alpha] - a_2 \sin\theta W \\
    f_4 = u \cos\theta + ws \sin\theta \\
    f_5 = -u \sin\theta + w\cos\theta \\
    f_6 = \]

Define

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

(6)

And

\[
    g(x)u = \begin{bmatrix} u_2 \\ k_1 u_1 \\ k_2 u_1 \\ 0 \\ 0 \\ 0 \end{bmatrix} 
\]

(7)

Then the system can be written as follows[6-8]

\[
    \begin{bmatrix} \dot{u} \\ \dot{w} \\ \dot{q} \\ \dot{\theta} \\ \dot{x} \\ \dot{z} \end{bmatrix} = \begin{bmatrix} f_{a1} \\ f_{a2} \\ f_{a3} \\ f_{a4} \\ f_{a5} \\ f_{a6} \end{bmatrix} + \begin{bmatrix} a_{11} u_2 + a_{13} k_2 u_1 \\ a_{22} k_1 u_1 \\ a_{31} u_2 + a_{33} k_2 u_1 \\ 0 \\ 0 \\ 0 \end{bmatrix} 
\]

(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:

\[ \delta_r = K_r (\theta_d - \theta) + K \int_0^t (\theta_d - \theta) \, dt + K_d \left[ \frac{d(\theta_d - \theta)}{dt} \right] \]  

(8)

\( \theta_d \) is expected angle of pitch [10-11]. choose

\[ K_p = 0.25 \]
\[ K_i = 0.0015 \]
\[ K_d = 1 \]  

(9)

Numerical Simulation

Assume \( u = 20 \text{ m/s} \), \( T_m = 5000 \text{ N} \), initial position \( x_e = y_e = z_e = 0 \). Other quantity of state is 0, choose \( \theta_d = 10^\circ \) [12-13], simulation results are as
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.

**References**


