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

Yidong Wang1,a, Junwei Lei2,b and Lingling Wang2,c

1the 91872th unit of PLA, Beijing, China
2Department of control engineering, Naval aeronautical and astronautical University
Yanti, 264001

awangyidong96107@163.com, bleijunwei@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 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:

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

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

\[
M^{-1} = \begin{bmatrix}
a_{11} & a_{13} \\
a_{22} \\
a_{31} & a_{33} \\
1 & 1 \\
1 & 1
\end{bmatrix}
\]

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

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[6-7]

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

Use the inverse matrix of \( M \)

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

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

where
\[
\begin{align*}
&f_1 = -(m + m_{s3}) w q + Q[C_{x1} \cos^2 \alpha + C_{x2} \sin(2\alpha) \sin(\alpha/2)] \\
&f_2 = (m + m_{s4}) u w + ma_2 q^2 + Q[C_{z1} \cos(\alpha/2) \sin(2\alpha) + C_{z2} \sin(2\alpha) + C_{z3} \sin(\alpha) \sin(\alpha)] \\
&f_3 = -ma_2 w q(-r v) + Q[C_{m1} \cos(\alpha/2) \sin(2\alpha) + C_{m2} \sin(2\alpha) + C_{m3} \sin(\alpha) \sin(\alpha)] - a_z \sin \theta W \\
&f_4 = q u \cos \theta + w \sin \theta \\
&f_5 = -u \sin \theta + w \cos \theta \\
&f_6 = u_1 \cos \theta + w \sin \theta
\end{align*}
\]

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

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

Then the system can be written as follows\[8-9\]
\[
\begin{align*}
\dot{u} &= \begin{bmatrix} f_{a1} \\ f_{a2} \\ f_{a3} \\ f_{a4} \\ f_{a5} \\ f_{a6} \end{bmatrix} \begin{bmatrix} a_{11} u_2 + a_{13} k_2 u_1 \\ a_{22} k_1 u_1 \\ a_{31} u_2 + a_{33} k_2 u_1 \\ 0 \\ 0 \\ 0 \end{bmatrix}
\end{align*}
\]

**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].
Choose[11-12]

\[ K_p = -0.01 \]

\[ K_i = 0 \]

\[ K_d = -0.1 \]  \hspace{1cm} (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 \( z_d = -100 \) [13-15], simulation results are as
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.

References

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