Design of Angle of Attack Tracking Controller for Aircraft Based on Angular Velocity Feedback

Li Hui[1], Li Heng[1], Li Jing[2] and Junwei Lei[1, a]

[1]College of Coastal Defense, Naval Aviation University, Yantai, 264001,China

[2]College of Weaponry engineering, Naval Engineering University, Wuhan, 430000,China

[a]leijunwei@126.com

Keywords: Attack angle; Angular velocity; Feedback; Aircraft; Control system

Abstract. Aiming at the simplified linear mathematical model of the pitch channel of a class of aircraft, a kind of angle of attack tracking controller is constructed by using the feedback scheme of attitude angular velocity and angle of attack. This kind of controller can avoid the use of angle of attack derivatives which are difficult to accurately measure, and at the same time can ensure the accurate tracking of the aircraft angle of attack. This kind of angle of attack stabilization controller can be widely used in aircraft control, trajectory design and scheme prediction, and has high application value.

Introduction

With the continuous upgrading of missile defense system [1-7], the global military powers require more and more high tactical and technical performance of missile weapons, which makes missiles rapidly develop from traditional subsonic and low altitude penetration to subsonic and supersonic combination and large airspace maneuver. Such as supersonic and hypersonic flight capability, high maneuverability in large or small airspace, etc.

With the increase of maneuverability, the level of angle of attack measurement [8-14] has been improved. It is more and more meaningful to study the attitude stabilization loop or overload stabilization loop by using angle of attack measurement to form angle of attack stabilization controller instead of the principle. Based on the above reasons, a class of angle-of-attack stabilization controller is studied in this paper.

Pitch Channel Model of Aircraft

The nonlinear pitch channel model of a kind of missile system can be described as

$$\begin{cases} \dot{\alpha} = \omega_z - \dfrac{qS}{mv} C_y(M_m, \rho, \alpha, \omega_z, \delta_z) \\ \dot{\omega}_z = \dfrac{qSL}{J_z} C_m(M_m, \rho, \alpha, \omega_z, \delta_z) \\ A_{yB} = \dfrac{qS}{m} C_y(M_m, \rho, \alpha, \omega_z, \delta_z) = n_{yB} g \end{cases}$$

(1)

And if the attack angle is very small, then its linear model can be written as

$$\begin{cases} \dot{\alpha} = \omega_z - a_{34}\alpha - a_{35}\delta_z = \omega_z - \dfrac{g}{v} n_y \\ \dot{\omega}_z = a_{24}\alpha + a_{22}\omega_z + a_{25}\delta_z \\ n_y = \dfrac{v}{g} a_{34}\alpha + \dfrac{v}{g} a_{35}\delta_z \end{cases}$$
(2)

And the control objective is to design a fractional order controller to make the missile attack angle to track the desired value.

Attack Angle Tracking Controller Design

Because of its powerful control performance, the PID control device has been widely applied in various fields. From simple single-loop control device to the collective control system consisting of hundreds of control devices, its variety can also be applied in all walks of life. At present, the well-known PID control device appeared and developed between 1915 and 40. Since then, various control methods have emerged in endlessly, but because of the advantages of simple structure, easy operation and robust to model errors of the PID control device, it can still play an important role in all walks of life. In the process of the research and development of new control methods, researchers have found that the PID control device can be used as the basic technical support to make various control algorithms evolve and upgrade.

We design a kind of controller similar to traditional PID controller as follows

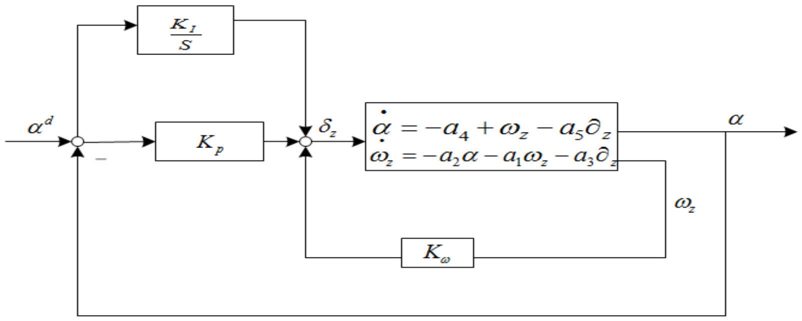

Fig. 1 Attack angle tracking system

And the control law is designed as

$$\delta_z = K_P\left(\alpha^d - \alpha\right) + K_I\int_0^t \left(\alpha^d - \alpha\right)dt + K_\omega\omega_z$$
(3)

And α^d is the idea attack angle , K_P and K_I are coefficients of controller。

Simulation and Figures

We can write a short simulation program by using the Simulink toolbox with Matlab software according to above analysis as following fig.2.

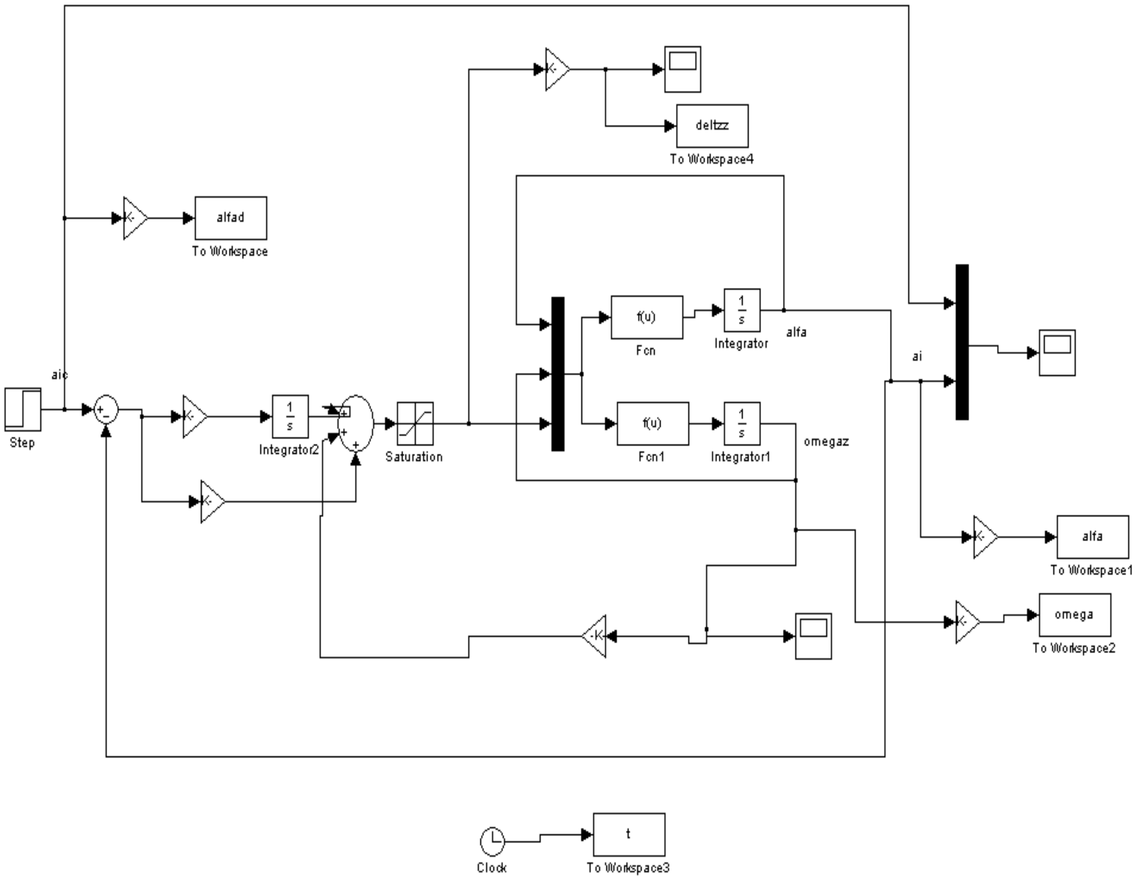

Fig.2 Simulink Program Structure

And we choose parameters of aircraft body as v=1000, $a_4 = 0.0215$, $a_2 = -0.396$, $a_1 = 0.0198$, $a_3 = 5.389$, $a_5 = 0.01$, and limit for actuator is 30degree, and choose control parameter as $K_\omega = 3.5$, $K_I = -2$, $K_P = -30$. And simulation result is shown as following figures.

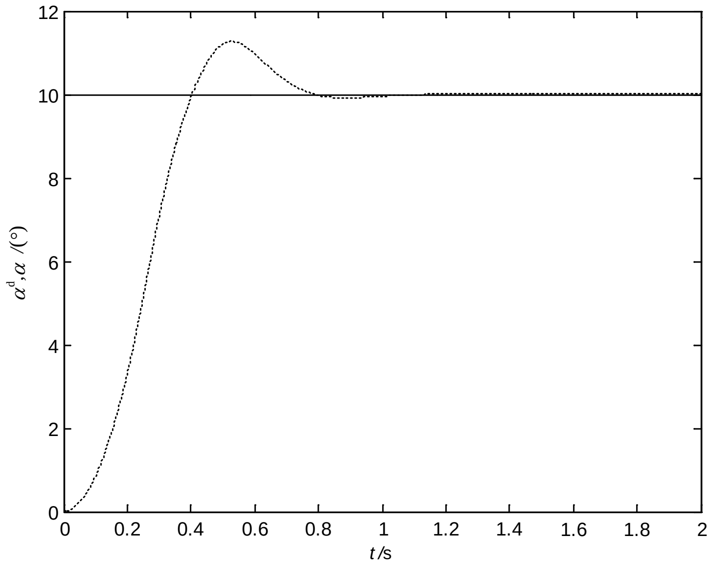

Fig.3 Attack angle

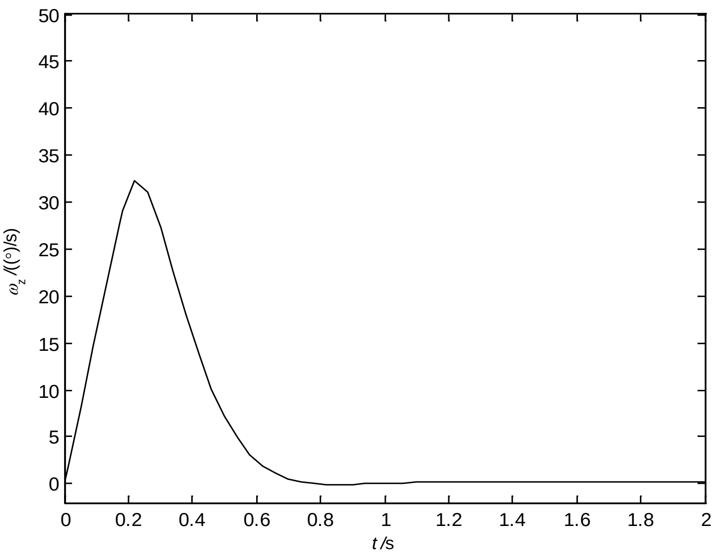

Fig.4 Pitch angle speed

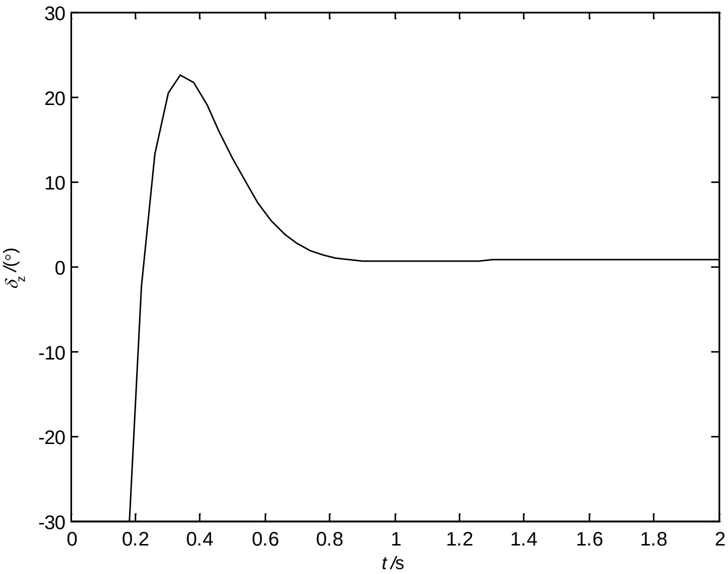

Fig.5 Actuator response

Result Analysis

According to the graph, the angle of attack can track the desired angle of attack quickly, the rising time is about 0.4 s, the adjusting time is less than 1 s, there is overshoot, less than 20%; the pitch angle speed quickly reduces to a smaller value. At first, the rudder deflection reaches saturation greatly, and then converges to a smaller value. Therefore, a class of angle of attack controller studied in this paper achieves the desired design goal, achieves the goal of fast angle of attack tracking, and the control structure is simple, and takes into account such factors as command limit and so on.

References

[1] Rosier L. Homogeneous Lyapunov function for homogeneous continuous vector field. Systems & Control Letters, 1992, 19, 467-473

[2] Sun B. & Gao Z. A DSP-based active disturbance rejection control design for a 1-kW H-bridge DC–DC power converter. IEEE Transactions on Industrial Electronics, 2005, 52, 1271-1277.

[3] Xia Y. Q., & Fu M. Y. Compound control methodology for flight vehicles. Berlin:

Springer-Verlag, 2013.

[4]Levant A. Higher-order sliding modes, differentiation and output-feedback control. International Journal of Control, 2003, 76, 924-941.

[5]Alexander L, Fradkov, Markov A Yu. Adaptive synchronization of chaotic systems based on speed gradient method and passification [J]. IEEE Trans Circuits System 1997, 44(10):905-912.

[6]. Dong X. Chen L. Adaptive control of the uncertain Duffing oscillator [J]. Int J Bifurcation and chaos. 1997, 7(7):1651-1658.

[7]. Tao Yang, Chun-Mei Yang and Lin-Bao Yang. A Detailed Study of Adaptive Control of Chaotic Systems with Unknown Parameters[J] . Dynamics and Control. 1998,(8):255-267.

[8]. M.T. Yassen. Chaos control of chaotic dynamical systems using backstepping design, Chaos Soliton Fract. 27 (2006) 537–548.

[9]Freidovich, L. B., & Khalil, H. K. Performance recovery of feedback linearization-based designs. IEEE Transactions on Automatic Control, 2008, 53, 2324-2334.

[10]Gao Z. Scaling and bandwith-parameterization based controller tuning. In American control conference, 2003:4989-4996.

[11]Guo B. Z. & Zhao Z. L. On the convergence of an extended state observer for nonlinear systems with uncertainty. Systems & Control Letters, 2011, 60, 420-430.

[12]Tournes C., Landrum D.B., Shtessel Y. and Hawk C. W.. Ramjet-Powered Reusable Launch Vehicle Control by Sliding Modes, Journal of Guidance, Control and Dynamics, V01.21, No.3, 1998, PP.409-415

[13]Marrison C. and Stengel R.. Design of Robust Control Systems for a Hypersonic Aircraft, Jourmal of Guidance, Control and Dynamics, V01.21, No.1, 1998, PP.58-63

[14]Wang Q. and Stengel R.. Robust Nonlinear Control of a Hypersonic Aircraft, Journal of Guidance, Control and Dynamics, V01.23, No.4, 2000, PP.577-585

[15] Khalil H. K. Nonlinear systems. New Jersey: Prentice Hall, 2002.