

# Simulation of open loop response of a kind of high speed aircraft with virtual flying conditions

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**Abstract.** A kind of numerical simulation method is used to testify the open loop response of a kind high speed aircraft. Since the final aim is to the testify the rightness of the system model and its corresponding air coefficients, so virtual flying condition is set to make the system more simple and more easy to be stable so that the simulation can be last for a longer time, which is very important and difficult for high speed aircraft. The attack angle and elastic shape of the aircraft is set to be constant so the virtual flying is constructed and it is reasonable for the aircraft, so it is effective and valid to testify the system model.

## Introduction

Considering that the complexity of the hypersonic control is integrated features by flexible form, the static instability of attack angle (or rapid divergence characteristics), the fast change characteristics of engine thrust, a given attack angle constant elasticity flight test is done in this paper after constant elasticity flight test. The purpose is to study height change on the influence of the attitude stability of hypersonic flight vehicle<sup>[1-4]</sup>. At the same time, the relationship between engine thrust and the oil supply factor is researched under the constant form condition of constant attack angle. It shows by digital simulation analysis that the flying height change of the aerodynamic force for a short period of time less than 5s, the impact is smaller. But the engine thrust produced by tapping oil factor changes greatly in a short time, and the change of thrust is produced under the condition that the oil supply factor does not increase<sup>[5-9]</sup>. It indicates that the engine oil supply factor and attack angle are more sensitive, so the engine is considered comprehensive in the design of control system.

## Model Description

Considering the elastic shape structure, a kind of pitch channel hypersonic aircraft model built according to Lagrange equation is released by USA air force as followed:

$$\dot{V} = \frac{T \cos \alpha - D}{m} - g \sin \gamma \quad (1)$$

Where

$$T = \bar{q}s(C_{T\phi}\phi + C_T + C_T^\eta\eta), D = \bar{q}SC_D$$

$$\dot{\phi} = -2\zeta\omega_n\phi - \omega_n^2\phi + \omega_n^2\phi_c, \omega_n = 5, \zeta = 0.7 \quad (2)$$

$$\dot{\gamma} = \frac{L + T \sin \alpha}{mV} - \frac{g \cos \gamma}{V} \quad (3)$$

$$L = \bar{q}SC_L$$

$$\dot{\alpha} = q - \dot{\gamma} \quad (4)$$

$$\dot{q} = \frac{M}{I} \quad (5)$$

$$M = z_T T + \bar{q} S \bar{c} C_M ,$$

$$\dot{h} = V \sin \gamma \quad (6)$$

$$\ddot{\eta}_i = -2\varepsilon_m \omega_{mi} \dot{\eta}_i - \omega_{mi}^2 \eta_i + N_i , \quad N_i = \bar{q} S C_{Ni} \quad (7)$$

$$\omega_{m1} = 21.17 = 17.56 , \quad \omega_{m2} = 53.92 = 48.78 , \quad \omega_{m3} = 109.1 = 95.6 ,$$

$$\varepsilon_m = 0.02 , \varepsilon_1 = \varepsilon_2 = \varepsilon_3 = 0.02$$

And  $V$  is speed,  $\gamma$  is the speed angle,  $\alpha$  is attack angle,  $Q$  is the attitude angle speed,  $h$  is the height.  $\phi$  is the oil supplying factor,  $\delta_c$  is the duck wing and  $\delta_e$  is the lift rudder.

### Simulation settings of free flying

In order to testify the rightness of the model of hypersonic aircraft, choose a initial height as  $h_0 = 85000 * 0.3048$ , initial speed as  $V_0 = 7846 * 0.3048$ , initial attack angle as  $\alpha_0 = 0.0174$ , and other initial state as:  $\gamma_0 = 0$ ,  $q_0 = 0$ ,  $\eta_{10} = 0.4588 * 0.3048 * 14.59$ ,  $\eta_{20} = -0.08726 * 0.3048 * 14.59$ ,  $\eta_{30} = -0.03671 * 0.3048 * 14.59$ , and set the oil supplying law as constant as  $\phi = \phi_c = 0.1$  and choose the control as  $\delta_c = 0$ , then the free flying test can be done by numerical simulation to make  $\dot{\alpha} = 0$ ,  $\dot{\eta}_i = 0$ , and simulation time is set as 0.5 second.

### Numerical Simulation and result analysis

With above model and air coefficients and set initial condition as above paragraph and write a program with m language in Matlab software, then the simulation can be done and simulation results can be shown as following figures.

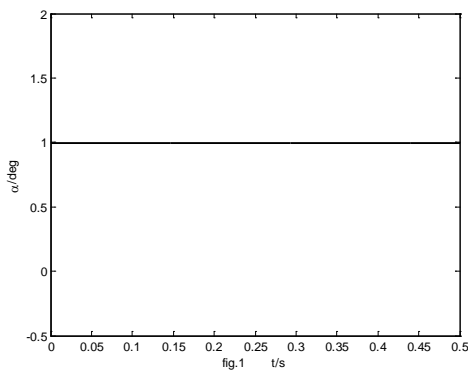


Fig 1 The curve of attack angle

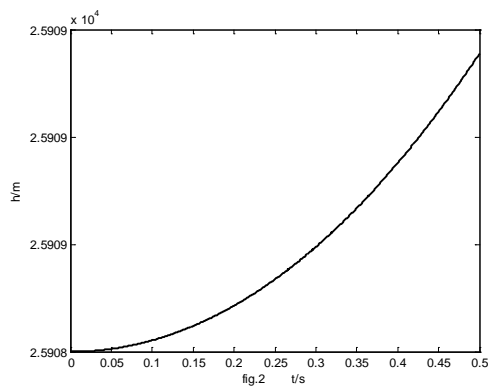


Fig 2 The curve of the height

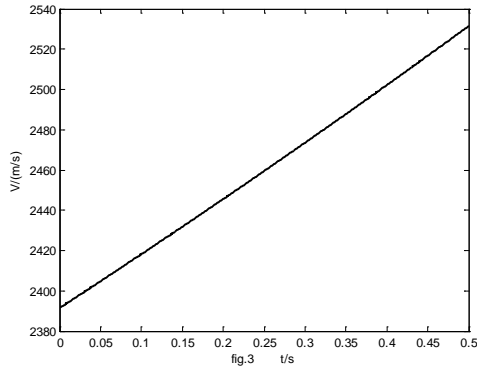


Fig 3 The curve of speed

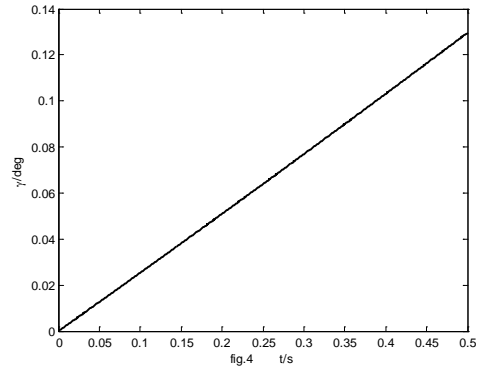


Fig 4 The curve of pitch angle

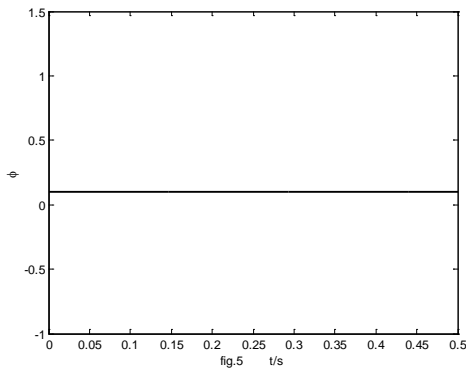


Fig 5 The curve of oil supplying factor

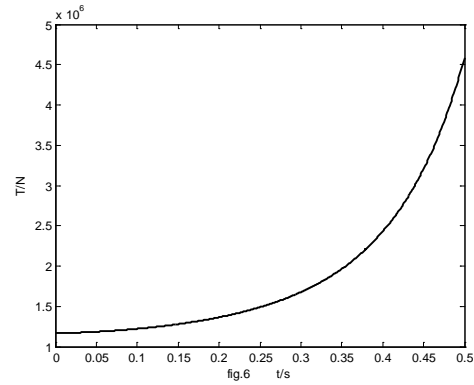


Fig 6 The curve of thrust

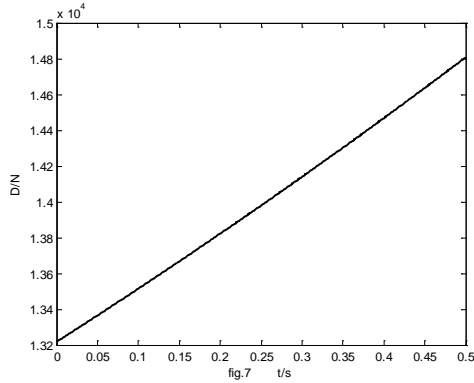


Fig 7 The curve of resistance

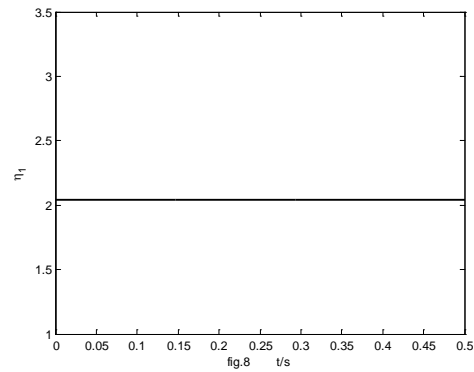


Fig 8 The state of first elastic shape

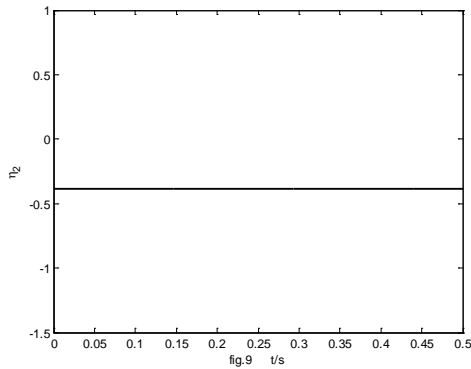


Fig 9 The state of second elastic shape

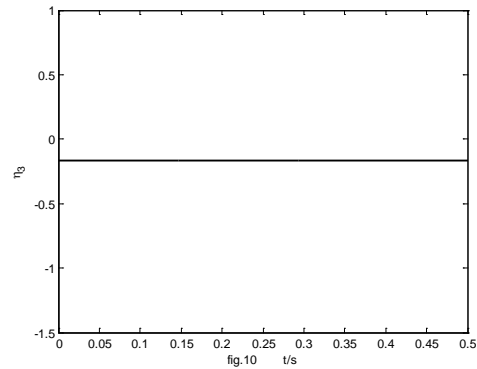


Fig 10 The state of third elastic shape

It can be seen from simulation that divergence speed of elevation angle decreases by 90% in 0.5 seconds flight of the fixed attack angle and elasticity. The thrust and drag are relatively stable at the same time. The change reduces more than 95%, the coupling of visible engine and attack angle is very serious. At this point, the flight is close to the missile at low speed, so flight time of no control can be increased to 5s or longer without causing divergence.

## Conclusion

The research shows that the stability control of attack angle is of great significance to the stable of engine thrust. So it also shows that hypersonic flight vehicle control and engine must be designed separately. The change of elastic body shape influencing on control is also very big, the trinity must be considered at the same time.

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