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RESEARCH ON SERVO CONTROL METHOD AND DAMPING CHARACTERISTICS OF ACTIVE CINTROL DEVICE

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Abstract

The application of side stick can save the installation space of the cockpit. Compared with the central bar, it has the advantages of improving the visibility of the front instrument panel and improving the anti-overload ability in combination with the reclining seat. However, due to the reduction of stroke and force sense, PIO is more likely to occur in some specific cases. Therefore, the active side stick is adopted to introduce flight parameters into the force-displacement characteristics, Connect the feeling of force by the pilot with the flight state of the aircraft to improve the handling quality of the aircraft. In this paper, three control methods of the active stick are studied. After simulation analysis, the dynamic characteristics of the three control methods are compared. The PID algorithm is used to find out the key so as to improve the rapidity and stability of system effectively. At the same time, the influence of the damping characteristics on the handling quality is studied. Through simulation analysis and experimental research, the factors affecting the damping characteristics are found. The simulation results and test results are analyzed to find out the laws.

Keywords: active stick; force control; control method;

1. Introduction

The research object of this paper is the simplified active control device system. As a part of the aircraft management system, the active control device system is composed with active stick and controller. The active stick mainly comprises a handle, a force sensor, a displacement sensor and a driving device. The driving device includes power amplifier and motor, which are used to realize force loading. Due to the intervention of the control computer, the active stick system can set the target load output characteristics as required, so as to combine with the aircraft state effectively and improve the control quality under the full flight envelope.

2. Research Object and Basic Principles

The controller receives the aircraft status information sented by the flight management computer (VMC) through the trunk, integrates the flight control commands, real-time adjusts the force, displacement, damping and other characteristics, solves the model force, converts it into a voltage driving signal after calculation, processing and amplification, outputs power to the active stick, drives the active stick and provides variable feedback force, providing the pilot with a sense of control[1], At the same time, the controller can complete the detection and fault diagnosis of the driving stick, and upload various fault information to the VMC. The basic schematic diagram of the active control device system is shown in Figure 1.

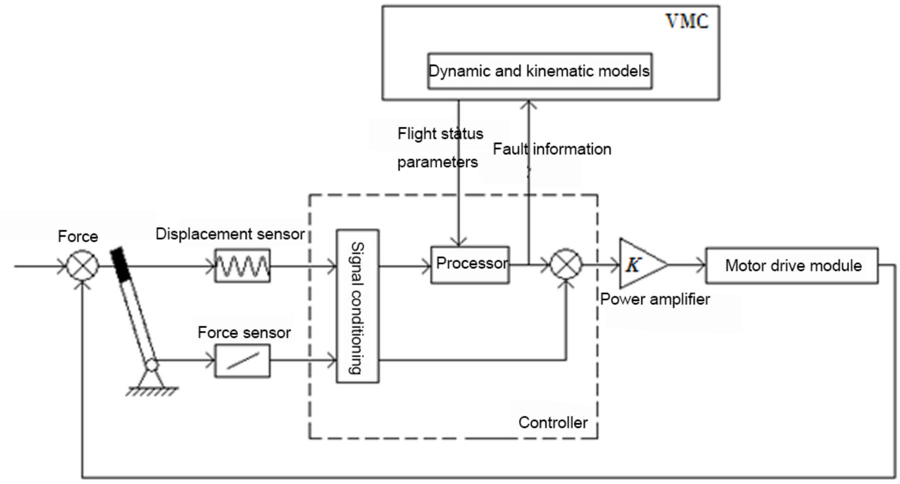


Fig.1 Schematic diagram of active control device system

3. Stick Model

The establishment of the stick model will affect the state of the stick after it is stressed. In order to facilitate the research, the active control device system is simplified, the mass and mechanical damping of the driving stick are converted to the connecting stick, and the equivalent model is shown in figure 2. The stick is regarded as a second-order spring damping system.

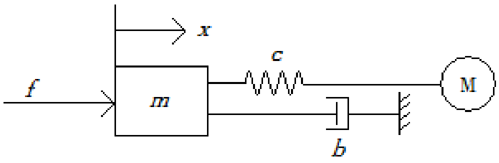


Fig.2 Equivalent model of driving lever

Here, the transfer function expressions of the output signals are given as position (1), velocity (2) and force (3).

$$x_s = \frac{f_s}{ms^2+bs+c} \tag{1}$$

$$x_s s = \frac{f_s - cx_s}{ms+b} \tag{2}$$

$$f_s = mx_s s^2 + bx_s s + cx_s \tag{3}$$

Among that：

b : effective damping of the system；

c : effective stiffness of the system;

m : system equivalent mass。

4. Research on Control Method

4.1 Three control methods

In order to improve the performance of the controller, this paper considers three control methods: position control, speed control and force control [6]. The difference lies in the input signal of the driving device. In this paper, F is the force converted to the grip point through the transmission ratio measured by the stick force sensor, and X is the linear displacement of the stick head after the angle of the stick is measured by the angular displacement sensor.

4.2 Simulation Results

The position response dynamic characteristic curves of the three control methods are drawn in one image, and the results are shown in Fig. 3.

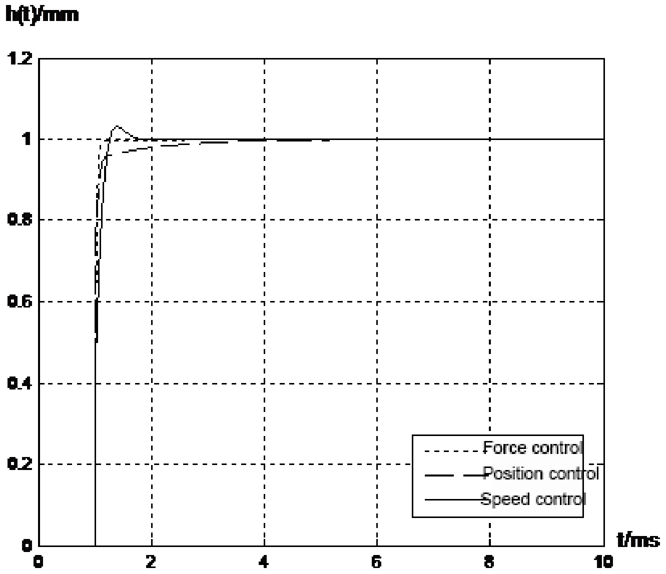


Fig. 3 Response curve when f= 100N

The dynamic characteristics of the response curves of the three control methods can be read out from Figure 3 and summarized in Table 1. The overshoot in the table is calculated according to the 2% tolerance zone. It can be seen that the force control method has the best dynamic characteristics, and the other two control methods can also reach the steady-state value, but the overshoot of speed control is large and the adjustment time of position control is too long.

Table 1 dynamic response comparison of three control methods

Serial number	Delay time (ms)	Rise time (ms)	Peak time (ms)	Adjustment time(ms)	Overshoot(%)
Position control	0.01	0.04	4.12	4.12	0.00
Speed control	0.02	0.18	0.36	0.46	3.33
Force control	0.00	0.00	2.7	0.00	0.00

5. Study on Damping Characteristics

5.1 Simulation Modeling

AMESim software is used to model the active control device system, and the change of damping characteristics is analyzed by changing the data of equivalent mass and starting force.

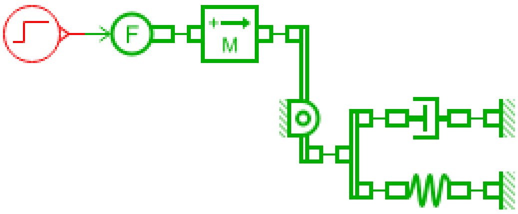


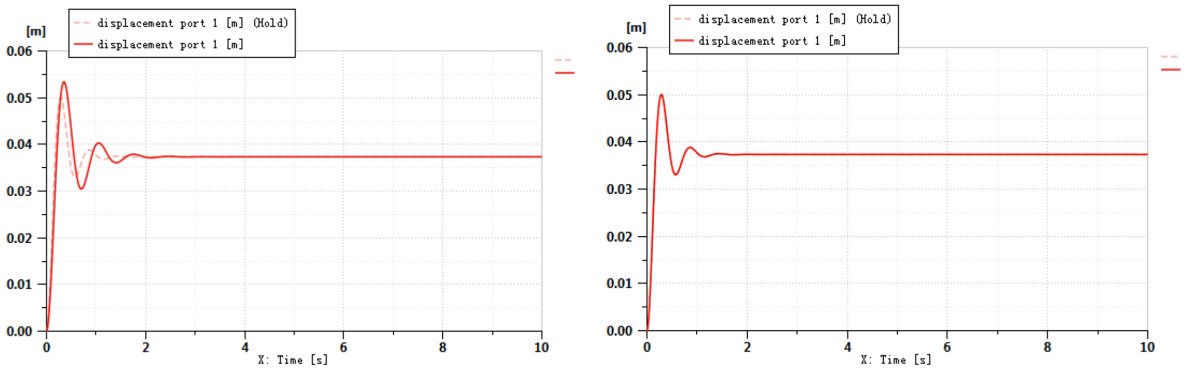
Fig.4 System model of active control device

5.2 Damping Characteristic test

Establish the test environment to carry out the damping characteristic test , adjust the inertia, friction and other parameters through the electric loading system, study the influence of different inertia, manipulation and other actions on the damping characteristic, collect more comprehensive data, and analyze the mechanism.

5.3 Simulation Results

The simulation results of damping characteristics is shown in Fig. 5.



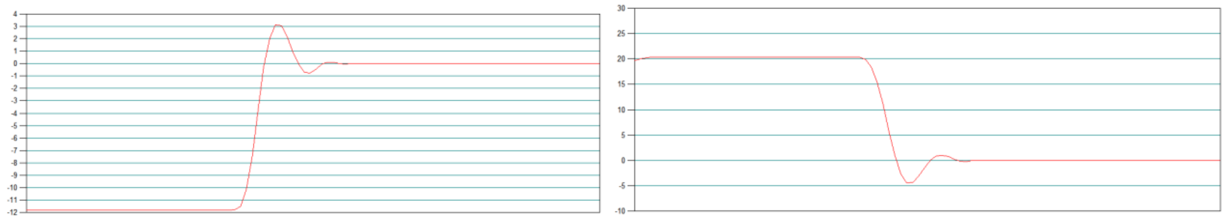
（a）Equivalent mass comparison （b）Starting force comparison

Fig. 5 Simulation results of damping characteristics

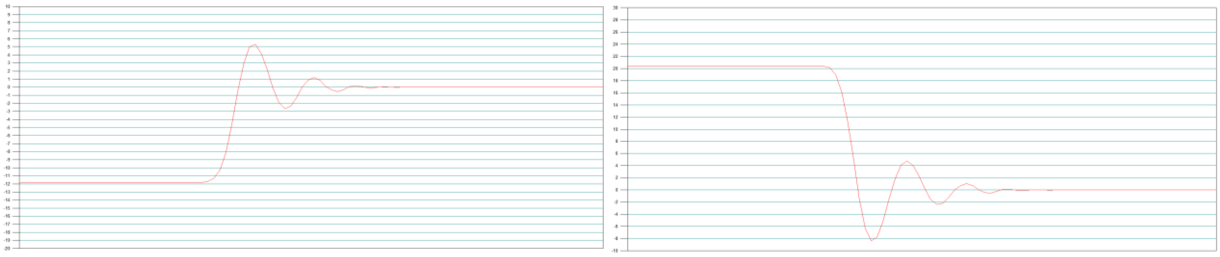
According to figure 5 (a), when the damping coefficient is constant, the system damping ratio decreases with the increase of the equivalent mass of the system. According to figure 5 (b), when other parameters are constant, the damping ratio of the system does not change significantly with the increase of starting force, which is different from the theoretical analysis results and needs to be further verified in the test environment.

5.4 Test Result

The test results of damping characteristics are shown in Fig. 6 and Fig. 7.



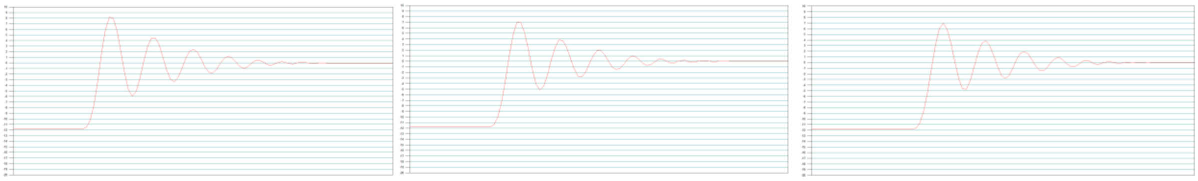
（a）Push forward / pull back results when the equivalent mass is m_a



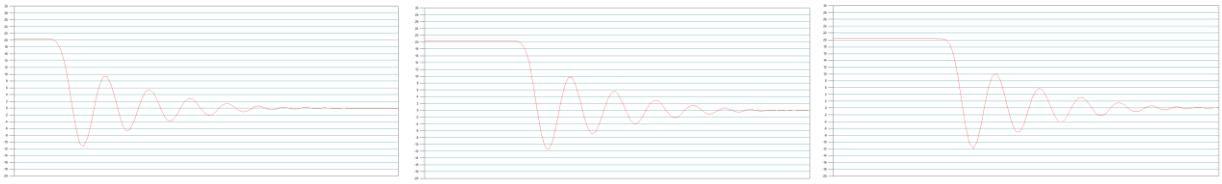
（b）Push forward / pull back results when the equivalent mass is m_b

Fig. 6 Simulation results of damping characteristics

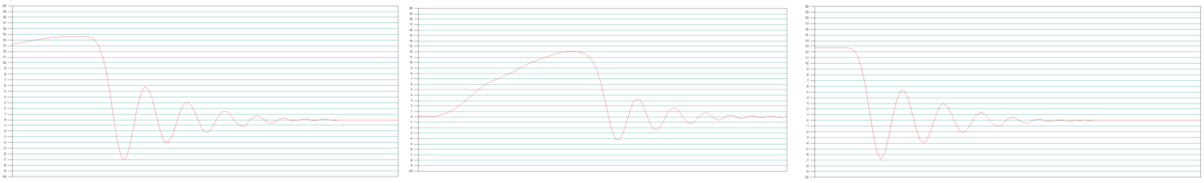
According to figure 6, when the damping coefficient is constant, the system damping ratio decreases with the increase of the equivalent mass of the system.



（a）Push forward test results



（b）Pull back 1/2 displacement test results



（c）Pull back full displacement test results

Fig. 7 Control action simulation results

The data in Table 2 are formed from the collected results. It can be seen that the damping ratio of the system decreases with the increase of the control displacement.

Table 2 Comparison of control action test results

Serial number	1	2	3	mean value
Push forward	0.7273	0.7379	0.6893	0.71817
Pull back 1	0.82	0.8333	0.8317	0.82833
Pull back 2	0.7176	0.7656	0.78	0.7544

6. Conclusion

This paper introduces the principle and model of the active control device system, simulates the control method of the active control device system, and observes the dynamic characteristics of the system in time domain under the three control methods by inputting step signals. The simulation results show that the force control method has the best dynamic characteristics. When adjusting the parameters, it is found that properly reducing the damping can increase the response rate of the system; Adjusting the torque feedback coefficient of the motor can reduce the steady-state error of the system and realize accurate control; The stability of the system will be affected by adjusting the amplification factor of the PWM device and the parameters of the regulator. At the same time, the simulation and Experimental Research on the damping characteristics are focused on, which is helpful to grasp the system characteristics more accurately and improve the control quality.

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