Study on the Simulink Model for the Testbed of the Environmental Control System of the Aircraft

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Abstract. The rapid rise in temperature and pressure and the Switching of high pressure and medium pressure state of the thermal dynamic testbed is realized by the switch between the two channels of gas supply. The dynamic performance depends mainly on the travel time of the switch valve. We simulate the class step change, which basically meet the needs of the dynamic test of the environmental control system. The dynamic rising temperature and pressure of the testbed depends mainly on the mixing of the cold and hot air and the adjustment of the regulating valve. It cannot be directly evaluated that how many dynamic performance indicators can be achieved.
The MATLAB/Simulink modelling software is used to build the thermal dynamic test platform system and control model. And we use this dynamic simulation technique to analyse the time of fast response.

1. Introduction
At present, the built thermal dynamic testbed in china mainly serve the development and maintenance of military aircraft. The object of these testbed is the finished product. The purpose is to determine whether the performance parameters of the component meet the static index of the design. Although the development of military aircraft will also verify the function of the system, only is in the middle and later stage of the project development. Its focus is the verification of the principle and the static performance index test. Therefore, the current thermal dynamic testbed has no dynamic performance.
In addition, environmental control system of the military aircraft is simpler than the civil aircraft. In the bleed air system of the military aircraft, there is no the high and low pressure switches, no fluctuation in the temperature and pressure of the gas supply. The coupling effect between parameters is not obvious and the problem of dynamic characteristics is not outstanding. Therefore, there is no test requirement for dynamic performance verification. Military aircraft increasingly pursue ultra-manoeuvrability and cause short time fluctuation of air entraining parameters, making the demand for the dynamic characteristics of the military aircraft environmental control system more and more obvious. Chinese users generally agree that dynamic characteristics are an important trend in the future development of thermal dynamic testbed, which will improve the practical value of environmental control system test. The system design of the environmental control of foreign aircraft manufacturers, who providing a large number of products to Boeing and Airbus through years, has accumulated rich experience in the design and test of testbed. But because of their test-bed technology is relatively closed, the technical parameters of the specific testbed are reluctant to be published to the outside world, and the research work is difficult.
System simulation technology is widely used in the field of aeronautics. In order to support decision analysis and reduce the cost of prototype and parametric testing of large physical prototypes, the environment control system (ECS) simulation is one of the important application directions of aircraft system simulation. Aircraft manufacturers attach great importance to air conditioning system simulation technology research to support system development, shorten the development cycle, improve energy efficiency and reduce costs [1]. In 2007, Boeing and the University of Hamburg in Germany started the loop control system functions (FLECS) project and aim to establish all components of the civil air-control system thermal model used to support the development of civil aircraft environmental control system [2]. Some scholars have also developed steady-state simulation models of air-conditioning systems to compare the advantages and disadvantages of the thermodynamic processes of different system configurations [3]. Müller and Airbus have jointly developed a dynamic simulation model library for supporting the design of aircraft air-conditioning systems [4]. The published literature shows that there are reports of simulation studies of system control [5]. However, the systems studied are mainly used in military aircraft system which have some differences with civil aircraft system. Therefore, the development of the system urgently need to verify and optimize for the aircraft during the development of engineering applications. In this paper, we use dynamic simulation technology to analyse the time of rapid response, and the simulation results can provide reference for subsequent supplier selection.

2. Methods
Matlab/Simulink modelling software is used to build a thermal dynamic testbed system and control model, as shown in Figure 1. So that the dynamic simulation technology is used to analyse the time of rapid response of the system. The data used in the simulation comes from the typical ECS components. Suppose the valves used are all butterfly valves with specific leakage. The parameters of the pipeline are the physical parameters of the stainless steel. The electric heater is a nonlinear model based on the conservation of energy. It is assumed that the time constant of the maximum flow is 3min. All component parameters can be changed according to the actual information provided by the later supplier, which does not affect the overall structure of the model.

![Figure 1. High pressure air supply channel in a thermal dynamic testbed](image-url)
In the model, the heating of the stainless steel electric heater is based on the principle that the electrical energy of the resistive load is converted into thermal energy and has the heating efficiency of 85%–95%. It is usually controlled by a silicon-controlled power regulator. It is based on the zero-crossing control technology of the cycle, which we usually call solid state relays. The heating voltage is constant, and the voltage is adjusted by the pulse pass signal, so the heater power is changed and the temperature is adjusted. This method is mostly used for the load of the large inertia heater. The mathematical model of the electric heater is as shown by equation 1:

\[
M_h C_h \left( \frac{dT}{dt} \right) = W \times C_p (T - T_a) + (Q / 1.056)
\]

(1)

Where \( M_h C_h \) is Thermal capacity of electric heater. \( W \) is the flow rate of air flowing through the electric heater. \( T_a \) is air temperature at the entrance, \( C_p \) is air specific heat and \( Q \) is the power rate. Factor 1.056 is a power unit conversion factor. Through the Manual Switch in the control model of pulse pass signal, the air temperature setting value at the outlet of the electric heater can be selected.

The dynamic performance of the testbed under the condition of fast rising pressure and temperature is analysed by using the model of the thermal dynamic testbed. It is assumed that the parameters of the high pressure air supply channel at the gas supply outlet of the testbed are \( P_1 \) and \( T_1 \) and the medium pressure gas channel is \( P_2 \) and \( T_2 \), and the set change curve is shown in Figure 2. \( P_1 \) has taken into account that the maximum gas supply pressure of the gas source of the thermal dynamic testbed is 350psia. The highest temperature of the \( T_1 \) setting is lower than the highest temperature of the outlet of the electric heater. The simulation results will show the thermal inertia effect of the pipe.

![Figure 2. The setting curves: (a) \( P_1 \) and \( T_1 \) at the outlet of high pressure air supply channel; (b) \( P_2 \) and \( T_2 \) setting curves at the outlet of medium pressure air supply channel](image-url)
3. Results
In the mixing process of cold and hot air, the air temperature at the outlet of the electric heater maintains a constant value. Because the air temperature at the outlet of the electric heater can reduce the influence of thermal inertia of the rear section pipeline, we compare the two cases of setting the outlet temperature of the electric heater to 1300°F and 1100°F. At 1300°F, the true response curve of T1 first passes through 1000°F at about 3010s, and the response curve of the sensor T1 is at 3060s, as shown in Figure 3; At 1100°F, the real response curve of T1 first passes through 1000 degrees F at about 3020s, and the response curve of the sensor T1 is at 3160s, as shown in Figure 4. There is no obvious difference in the change of pressure in the two cases.

According to the information shown in Figure 3, if a high temperature electric heater is used, the time required for the T1 temperature to rise from 500°F to 1000°F is only about 10s, and the stability time is 60s. The time required for T2 to rise from 300°F to 550°F is only about 5s, and the stability time is 40s, as shown in Figure 5. The overshoot of the test bed is large, and the test part has the risk of 5s over temperature.

![Figure 3](image)

**Figure 3.** Response curves of T1(a) and P1(b) at the outlet of high pressure air supply channel (1300°F of electric heater)
Figure 4. Response curves of T2(a) and P2(b) at the outlet of high pressure air supply channel (1300°F of electric heater)
4. Conclusion
In this paper, the Simulink model for the testbed of the environmental control system of the aircraft was studied. The results show that the higher the outlet temperature of the electric heater is, the faster the response characteristic of the temperature output of the testbed is. And the temperature overshoot is more severe. The pressure response rate is not affected. The system decoupled temperature and pressure on the structure. This dynamic performance can fully meet the needs of rapid heating up of the environmental control system and overcome the conventional furnace heating mode in the domestic environmental control laboratory. Because of the thermal inertia of the conventional electric furnace and the high thermal inertia of the back-end pipeline, the dynamic performance is completely limited to its real-time heating rate. To achieve the heating up from 350 to 1000 degrees, it is basically needs over 5min to reach a stationary state, which leads to no way to simulate the fast-changing temperature at the entrance of the test.

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