Research on Modelling and Simulation Method of Low Pressure and Temperature Environment Chamber

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Abstract. This paper provides modelling and simulation method for low pressure and temperature environment chamber. The environment chamber internal air-flow organization with air deflector and anisotropic damping plate are calculated and optimized. The results show that under the condition of low pressure, adopting the above airflow organization control method can ensure that the temperature difference of the core area is less than 1 degree. At the same time, a preliminary analysis of the environmental chamber loaded with test parts is carried out. The flow field and temperature field in the environmental chamber are greatly affected by large size test pieces. In order to keep the temperature uniform, the wind speed in the test section should be adjusted according to the test pieces. The results show that the method of the temperature uniform optimization is effective. The results in this paper have a certain reference value for the design of large environmental chambers.

1. Introduction
At present, the cruise height of large passenger aircraft can reach more than 40000ft, and it will last for more than ten hours. During the flight, the atmospheric environment condition will change greatly. The temperature will change from 65 degree below zero to more than 50 degree, and the pressure can less than 10 kPa[1-3]. From the point of view of design and verification, functional design is to separate the various professions, systems, and physical quantities to achieve their specific functions. On the other hand, system verification is bottom-up, and ultimately it is to be verified as a whole, in addition to system integration, environmental integration, and installation integration, for example, cabin temperature control, achieved by low-pressure pipeline air supply, system integration refers to The integration of the upstream mixing chamber air conditioning package, the environment integration refers to the hot and cold environment outside the machine, the installation integration refers to the low-pressure pipeline installed in the passenger cabin, the “installation” in FAR 25.1309, including the above three aspects, to achieve the equivalent These test environments are needed for verification as a whole.

In order to verify the reliability of the design, one of the important ways is to carry out the high altitude environment simulation test on the ground. The high altitude environment simulation system is the main test equipment used to build the external temperature environment of the aircraft, and, enhance the performance test of the aircraft environmental control system and the thermal comfort test of the aircraft cabin. For the environment chamber, the temperature uniformity is one of the most important technical indicators, which directly determines the performance of the environment
chamber[4]. For using air convection heat transfer, the temperature distribution is directly related to the air flow organization in the environmental chamber.

2. High altitude environment simulation
The high altitude environment is a low pressure environment, and low air density environment, therefor, the heat transfer coefficient is extremely small. And generally the internal volume of environment chamber, can reach thousands of cubic meters, to meet temperature uniformity in such a large space under low pressure environment is very difficult[5]. At home and abroad usually use orifice plate air supply or cold plate radiation cooling mode, or a combination of both, but when there is a big test of heating power, it is difficult to control the temperature in the chamber, because the small average wind speed and cabin air flow resistance[6,7]. In this paper, the structure of air flow with anisotropic damping laminates is studied, in Oder to optimizes the temperature uniformity in a large space environmental chamber.

3. Technology realization
The physical model of the large environmental chamber is shown in Figure 1. The main characteristics are: (a) the air distribution in the test area of the environmental chamber is a horizontal air supply mode, and the internal circulation is carried out through the top air supply cavity and the bottom air supply cavity, as shown in Figure 2. (b) the top air supply cavity and the bottom air supply cavity contain a dynamic section. The power section includes the air cooling heat exchanger component and the air re-circulation fan component. (c) there are air deflectors and anisotropic damping laminates on the front and rear ends of the test area of the environmental chamber. The damping characteristics of the damping laminates in horizontal and vertical directions can be designed according to needs.

4. Sections, subsections and subsubsections
Using CFD technology, the flow field and temperature uniformity are simulated and analysed. The analysis shows that by controlling the air flow organization of the damping layer, the flow field can be realized under the condition of small pressure loss, which ensures the high / low temperature uniformity of the low pressure environment in the high-altitude cabin.

4.1. Mathematical model and boundary condition
The grid is divided into three parts: the dynamic section of the environmental chamber, the damping layer, the test section and the section of the head. and the grid with the test piece contains one test area more. The whole grid size is set to 0.2m, the head of rotary section of the fluid near the wall region, etc. for partial encryption, as shown in Figure 3.
The grid of environmental chamber is shown in Figure 3.

In the calculation, only the steady state operation is considered. The K-Epsilon turbulence model is adopted. The damping layer area is porous media model, and the corresponding viscous resistance coefficient and inertia drag coefficient are set up. The power cabin heat exchanger model, dynamic inflow and outflow end section adopts a fan wall condition, heat flow setting cabin surface boundary conditions. The definition of each working condition is shown in Table 1.

Table 1. Conditions and damping layer features

| Case  | Fan pressure (Pa) | Attitude (ft) | horizontal inertia resistance coefficient (1/m) | vertical inertia resistance coefficient (1/m) |
|-------|------------------|---------------|-----------------------------------------------|---------------------------------------------|
| Case1 | 800              | 0             | 40                                           | 20                                          |
| Case2 | 800              | 0             | 50                                           | 20                                          |
| Case3 | 800              | 0             | 100                                          | 20                                          |
| Case4 | 1000             | 0             | 60                                           | 20                                          |
| Case5 | 500              | 35000         | 50                                           | 20                                          |

4.2. Characteristics of flow field and temperature field

The flow field calculation result is shown in Figure 4. Taking CASE1 and CASE2 as example, the CASE1 horizontal inertia resistance coefficient is small, in the center a high speed jet format, the core area of the jet can be extended to the regional test center, test flow field uniformity is poor; in CASE2 maintain the vertical inertia resistance coefficient, improve the level of horizontal inertia resistance coefficient, flow field uniformity is obviously improved, and the average air speed of test area is 4.5 m/s, which is 4.6 m/s in CASE1, the changing is little. In CASE 3 continued to increase horizontal inertial resistance coefficient to 100/m. The central location of test area was cavitating and the flow field became uniform. The mean velocity 3.9 m/s of test area was significantly lower than that of CASE1 average flow velocity 4.6 m/s.

In order to get higher average velocity of test area, CASE 4 increased fan static pressure and adjusted horizontal inertia resistance coefficient, and the average velocity of test area increased to 5.6 m/s. In conclusion, the flow field control can be realized by adjusting the resistance characteristics of the damping plate. Proper horizontal inertial resistance and vertical inertia resistance can significantly improve the uniformity of the flow field and have no obvious effect on the average speed.
For the low pressure environment, because the air density is low, the air density at 35000 feet is only about 1/4 of the sea level. The static pressure provided by the recirculating fan will decrease, and the flow resistance will also decrease. Taking CASE5 as an example, the average velocity of the test area is 5m/s, and the uniformity is better. Near the cabin wall temperature is high, but the test area was not significantly affected by wall temperature, as shown in Figure 5.

In order to evaluate the environment chamber temperature uniformity, a certain area which is constant distance to cabin wall, roof and floor is a distance is define as the core region. The center of the core area, the center of the surface and the center of the body are taken as the object of investigation. Calculation of extreme cold (XC) -55℃, cold temperature(C) -10℃, hot (H) 40℃, extreme hot (XH) 70℃ situation, examine the temperature contrast, the result is shown in Figure 6, the temperature difference ΔT of each point in the core area is were less than 1℃.
5. Conditions with test piece

In order to verify the environmental chamber design, working conditions with the test parts were studied. The ambient temperature set to 276K, the surface temperature of the test parts was set to 320K, and the surface area of the test parts was 138m². The calculation results show that the flow field in the test area is well uniform and presents a laminar flow state as shown in Figure 7. The temperature uniformity around the test parts is better. The average air velocity is 3.2m/s, and the total heat transfer is 65kW. Surface streamline and heat flux density of test parts is shown in Figure 8.

When the test parts are placed, especially the large size test parts, the obstruction in the environment cabin is greater, which will significantly change the flow field in the environment chamber. When the heat source exists in the test piece, the heat load generated by the heat source in the test chamber is usually larger than that in the environmental chamber itself. After placing the internal heat source, the temperature field in the environmental chamber will be significantly changed. Therefore, after placing test pieces in the environmental chamber, the temperature uniformity in the cabin will be greatly affected. In order to keep the temperature uniform, it is necessary to adjust the wind speed in the test section; and the degree of the specific influence needs to be analysed according to the calorific conditions of the test piece.

Figure 6. Temperature contrast in the core area

Figure 7. Cross section flow field with test piece
6. Conclusions
As the degree of integration of complex systems increases, the performance range of each system that can be verified is declining, and the boundaries of each system cannot be verified. This is an inherent contradiction. The solution is to think about the transfer of some flight tests to the ground laboratory. In order to achieve uniform design and requirements of the internal temperature of the environmental chamber, and to meet the real test scenario, In this paper, a horizontal wind blows and air distribution scheme using anisotropic damping laminates is designed for the environment chamber. By adjusting the drag characteristics of the damping laminates, the flow field can be controlled, and the temperature homogeneity can be simulated in the large space high altitude environmental chamber. The results show that in low pressure environment the chamber core area temperature different can less than 1°C.

When placing large size test pieces in the environmental chamber, the flow field and temperature field in the environmental chamber will be greatly affected. In order to keep the temperature uniform, the wind speed in the test section should be adjusted according to the calorific value of the test piece.

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