Simulation Research on Air Distribution of Electronic Equipment Bay Ventilation System of Civil Aircraft

Jin Rongjia(✉) and Yan Xudong

Shanghai Aircraft Design and Research Institute, Shanghai 201210, China
283912047@qq.com

Abstract. The electronic equipment bay ventilation system of civil aircraft is generally composed of a blowing subsystem and an extraction subsystem, which provides ventilation and cooling functions for the electronic equipment bay area. The quality of its design directly affects the reliability of the electronic equipment and thus directly affects the aircraft safety. In this paper, the electronic equipment bay ventilation system of a certain type of civil aircraft is taken as the research object, and the air distribution is investigated of the blowing subsystem and extraction subsystem. The Flowmaster is used to model the electronic equipment bay ventilation system, and the air distribution simulation of the blowing subsystem and extraction subsystem of the electronic equipment bay is carried out. The results show that, the air distribution simulation by using the restrictor ring size calculated by the flow balancing model can meet the air distribution design requirements of the electronic equipment bay ventilation system, and a reference for the design of electronic equipment bay ventilation system of civil aircraft is provided.

Keywords: Electronic equipment bay ventilation system · Air distribution · Simulation

1 Introduction

The function of the electronic equipment bay ventilation system is to provide ventilation and cooling functions for aircraft electronic equipment bay and onboard electronic equipment to ensure the normal and reliable operation of onboard electronic equipment [1]. At present, with the development of modern science and technology, the application of onboard electronic equipment is becoming more and more extensive, so the thermal load caused by electronic equipment increases sharply [2]. If the thermal cannot be dissipated in time, it will directly affect the normal operation of the electronic equipment, and even cause the damage of the electronic equipment, thereby greatly reducing the performance of the aircraft's onboard electronic equipment system. Therefore, the air distribution of the electronic equipment bay is a key issue in aircraft environmental control system.

In current studies, researches are mainly through experimental or simulation methods. For the experimental of air distribution, Liu et al. investigated the influence of air

Chinese Society of Aeronautics and Astronautics: CASTYSF 2022, LNEE 972, pp. 270–277, 2023.
https://doi.org/10.1007/978-981-19-7652-0_25

distribution on aerodynamic field and combustion performance in a 0.9 MW arch-fired furnace [3]. Nielsen et al. studied the air distribution which is in rooms or with the mixing ventilation and displacement ventilation [4]. Kumar et al. investigated the effect of tile air flow rate on the server air distribution at various locations in the rack [5]. Krajcik et al. studied the air distribution, ventilation effectiveness and thermal environment in a simulated room [6]. For the simulation of air distribution, Wang et al. used a multizone network program, and provided a theoretical basis for improving the accuracy for modeling air distribution in buildings [7]. Domanski et al. established a simulation model of a plate-fin, air-to-refrigerant heat exchanger based on a tube-by-tube approach [8]. Depypere et al. used the Fluent performed for a Glatt GPCG-1 fluidized bed coater and obtained a more homogeneous airflow towards the distributor [9]. Zhang et al. introduced the Flowmaster and showed the application in HVAC [10]. In conclusion, there is no studies on air distribution in the electronic equipment bay.

In this paper, the electronic equipment bay ventilation system of a certain type of civil aircraft is carried out as the research object, and the air distribution is investigated of the electronic equipment bay ventilation system, and a reference for the design of electronic equipment bay ventilation system of civil aircraft is provided. The Flowmaster is used to model the electronic equipment bay ventilation system, and the simulation of the blowing air and extraction air of the electronic equipment bay ventilation system is carried out.

2 Simulation Models and Boundary Condition

In this paper, the aerospace module of Flowmaster is used to model the ventilation system of the electronic equipment bay, and the physical model is converted into a simulation model. For the simulation of the electronic equipment cabin ventilation system, the incompressible steady-state analysis model is chosen.

For the modeling of the electronic equipment bay ventilation system, only the air of the working parameters of the electronic equipment blowing fan and extraction fan has an influence on the air distribution, so the blowing fan and the extraction fan are simplified as flow sources in the simulation The comparison table between the physical model and the simulation model of the electronic equipment bay ventilation system is shown in Table 1.

Table 1. The physical model and computational model comparison table

Boundary name	Boundary type
Blowing fan/Extraction fan	Flow source
Electronic equipment bay ducting	Pipe, bend, junction, transition
Restrictor ring	Orifice
Each blowing/extraction inlet or outlet	Pressure source

According to the above modeling principles, the modeling results of a certain type of civil aircraft electronic equipment bay ventilation system are shown in Figs. 1 and 2.

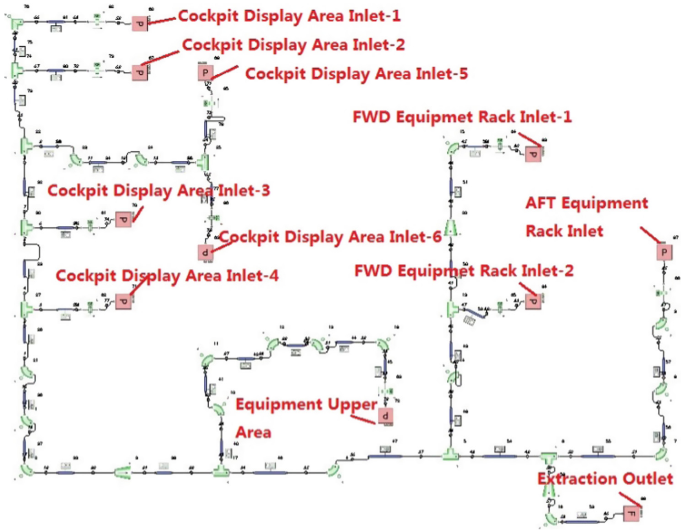

Fig. 1. Simulation model for extraction subsystem of a certain type of civil aircraft electronic equipment bay ventilation system

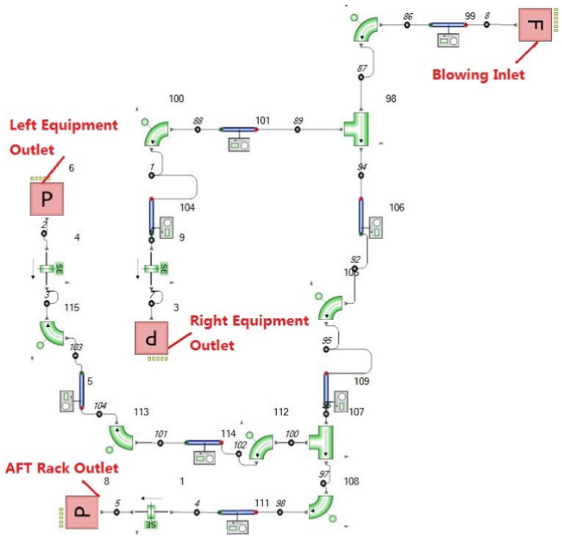

Fig. 2. Simulation model for blowing subsystem of a certain type of civil aircraft electronic equipment bay ventilation system

Figures 1 and 2 are respectively is the simulation model for the air distribution of extraction subsystem and blowing subsystem in the electronic equipment bay. In the extraction subsystem model, the inlet is each extraction inlet, which is expressed in the form of a pressure source; the air outlet is an extraction fan, expressed in the form of a flow source. In the blowing subsystem model, the inlet source is a blowing fan, which is represented in the form of a flow source; the outlet is the left electronic equipment inlet, the right electronic equipment inlet and the after equipment rack inlet, which are expressed in the form of pressure sources. Each extraction inlet or blowing outlet should be adjusted through the orifice of the restrictor ring on the ducting. The incompressible flow balancing model is used in the design calculation of the restrictor ring to obtain the diameter of the restrictor hole corresponding to each extraction inlet or blowing outlet.

The key to establish air distribution simulation model with the Flowmaster is to set the input parameters of the model. For components such as pipes, bends, transitions, junctions, restrictor rings, etc., the Flowmaster has a variety of mathematical models to choose from, and has certain engineering data support [11]. The parameter types of each simulation element are shown in Table 2.

Table 2. Air simulation parameter table of electronic equipment bay ventilation system

Component types	Parameter 1	Parameter 2	Parameter 3	Parameter 4
Pipe	Diameter	Length	Roughness	Friction coefficient
Restrictor ring	Pipe diameter	Orifice diameter		
Flow source	Flow	Temperature		
Pressure source	Pressure			

For the electronic equipment bay ventilation system simulated in this paper, the parameter settings of each component are designed according to the system parameters of a certain type of civil aircraft.

According to the development experience of other aircrafts, the total design air of the blowing subsystem is 320 L/s and the total design air of the extraction subsystem is 680 L/s. The boundary conditions of each inlets or outles of the electronic equipment bay ventilation system are provided in conjunction with the air distribution model of Figs. 1 and 2. Specifically, as shown in Table 3.

3 Simulation and Results Analysis

In this paper,the simulation steps of the air distribution of the electronic equipment bay ventilation system of a certain civil aircraft including the simulation of the orifice matching of the restrictor ring and the check of the air distribution results.

The flow balancing model is used to match the size of the restrictor ring on each branch, and the initial value of the restrictor ring orifice on each branch can be obtained. According to the development experience of other aircrafts, the actual current restrictor ring orifice is usually in units of 0.125in. After conversion, the rounded value of the current restrictor ring aperture can be obtained, as shown in Table 4.

The air distribution of the electronic equipment bay ventilation system according to the value of the restrictor ring orifice calculated in Table 4, compared with the design boundary conditions and the simulated flow value of each branch, and the flow deviation,

Table 3. The simulation boundary conditions of air distribution in the electronic equipment bay

Types	Inlet or Outlet	Air distribution (L/s)
Extraction air of the electronic equipment bay	Cockpit display area inlet-1	8
	Cockpit display area inlet-2	8
	Cockpit display area inlet-3	8
	Cockpit display area inlet-4	8
	Cockpit display area inlet-5	4
	Cockpit display area inlet-6	4
	FWD equipment rack inlet-1	20
	FWD equipment rack inlet-2	20
	AFT equipment rack inlet	280
	Equipment upper area	320
Blowing air of the electronic equipment bay	AFT rack outlet	220
	Left equipment outlet	50
	Right equipment outlet	50

and the air distribution of each branch in the electronic equipment bay. The results are shown in Table 5.

According to the simulation results in the table, it can be seen that the flow deviation between the calculated value of the air distribution in each temperature zone of the electronic equipment bay and the design value is within ±5%. Therefore, it can be considered that the air distribution by using the diameter of the restrictor orifice calculated by the flow balancing model and the converted diameter of the restrictor orifice can meet the air distribution requirements of the electronic equipment bay ventilation system.

4 Conclusion

In this paper, the electronic equipment bay ventilation system of a certain type of civil aircraft as the research object, and investigates the air distribution of the electronic equipment bay ventilation system. The electronic equipment bay ventilation system was modeled by the Flowmaster, and the air distribution of blowing subsystem and extraction subsystem in the electronic equipment bay was simulated.

The results show that the air distribution simulation by using the restrictor ring size calculated by the flow balancing model can meet the air distribution design requirements of the electronic equipment bay ventilation system.

Table 4. Simulation results of restrictor ring orifice

Types	Branch name	Initial value of restricting ring orifice (m)	Rounded value of restricting ring orifice (in)
Extraction subsystem	Cockpit Display Area Inlet-1	0.016	0.625
	Cockpit Display Area Inlet-2	0.016	0.625
	Cockpit Display Area Inlet-3	0.016	0.625
	Cockpit Display Area Inlet-4	0.016	0.625
	Cockpit Display Area Inlet-5	0.011	0.375
	Cockpit Display Area Inlet-6	0.011	0.375
	FWD Equipment Rack Inlet-1	0.022	0.875
	FWD Equipment Rack Inlet-2	0.022	0.875
	AFT Equipment Rack Inlet	0.079	3.125
	Equipment Upper Area	0.094	3.75
Blowing subsystem	AFT Rack Outlet	0.071	2.75
	Left Equipment Outlet	0.035	1.375
	Right Equipment Outlet	0.036	1.375

Table 5. Air distribution simulation results of the electronic equipment bay ventilation system

Types	Branch Name	Design boundary conditons (L/s)	Simulation value of flow (L/s)	Flow deviation (%)
Extraction system	Cockpit Display Area Inlet-1	8	8	0
	Cockpit Display Area Inlet-2	8	8	0
	Cockpit Display Area Inlet-3	8	8	0
	Cockpit Display Area Inlet-4	8	8	0
	Cockpit Display Area Inlet-5	4	4	0
	Cockpit Display Area Inlet-6	4	4	0
	FWD Equipment Rack Inlet-1	20	20	0
	FWD Equipment Rack Inlet-2	20	20	0
	AFT Equipment Rack Inlet	280	268	−4
	Equipment Upper Area	320	330	+3
Blowing system	AFT Rack Outlet	220	231	+5
	Left Equipment Outlet	50	49	−2
	Right Equipment Outlet	50	49	−2

References

1. Bruno, L.J., Hipsky, H.W., Jr. D.E.A, et al.: Aircraft Environmental Control System: US20190225343A1[P] (2019)
2. Shou, R.Z., He, H.S.: Aircraft Environment Control. Beihang University Press (2004)
3. Liu, R., Hui, S., Yu, Z., et al.: Effect of air distribution on aerodynamic field and coal combustion in an arch-fired furnace. Energy Fuels **24**, 5514–5523 (2010)
4. Nielsen, P.V., Topp, C., Sønnichsen, M., et al.: Air distribution in rooms generated by a textile terminal-comparison with mixing and displacement ventilation. ASHRAE Trans. **8**, 733–739; Ashrae Trans. **111**, 733–739 (2005)
5. Kumar, P., Joshi, Y.: Experimental investigations on the effect of perforated tile air jet velocity on server air distribution in a high density data center. In: IEEE. IEEE (2010)
6. Krajcik, M., Simone, A., Olesen, B.W.: Air distribution and ventilation effectiveness in an occupied room heated by warm air. Energy Build. **55**, 94–101 (2012)

7. Wang, L., Chen, Q.: Theoretical and numerical studies of coupling multizone and CFD models for building air distribution simulations. Indoor Air **17**(5), 348–361 (2010)
8. Domanski, P.A.: Simulation of an evaporator with nonuniform one-dimensional air distribution. ASHRAE Trans. **97**, 793–802 (1991)
9. Depypere, F., Pieters, J.G., Dewettinck, K.: CFD analysis of air distribution in fluidised bed equipment. Powder Technol. **145**(3), 176–189 (2004)
10. Zhang, G.P., X.N., Zhang, W.P., et al.: Application of Flowmaster in HVAC. Refrigeration Air-Condition (2006)
11. Wang, G.W., Wu, C.Y., et al.: Optimization design and experimental verification of cabin air distribution for civil aircraft. Civil Aircraft Des. Res. **4**, 4 (2015)