Research on the Model and Application of Airborne Virus Transmission in Cabin

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Keywords: Aircraft cabin, virus, airborne, simulation modeling, fluent, CFD.

Abstract: Aiming at the virus spread in the cabin, the cabin environment was simulated. Using the combination of fluent and CFD in ANSYS, the environment in the cabin was simulated by researching the data, and the data was analyzed to determine the probability of droplets spreading within a certain range , Improve the construction of the air circulation system in the cabin, reduce the transmission probability of respiratory infections and viruses in the cabin.

1. Background

With the spread of influenza and some pathogenic bacteria through civil airliners in recent years, the study of cross-transmission of pathogens in environments with poor air circulation and airtightness has become particularly important. Virus transmission in the cabin refers to harmful bacterial factors. The combination of chemical factors and air in the cabin has dangerous characteristics such as infectiousness and pathogenicity. This type of airborne bacteria spreads quickly and spreads widely. Compared with other confined spaces, the cabin is more unique, and its unique characteristics directly affect its probability of spreading germs.

2. Cogitation of the Research

First, conducting in-depth understanding and analysis of virus attributes and transmission modes, and then understanding the environmental structure of different aircraft cabins. Taking a part of the cabin size as a reference by simulating part of the cabin environment to the virus transmission in the cabin. Setting some boundary conditions to simulate the air environment of the cabin. Assume that a patient is carrying the SARS virus and use existing data to simulate the environment in the cabin. Assuming the spread speed of virus droplets, use the modeling software CFD to establish a mesh model and the simulation software ANSYS to perform flow field analysis to calculate the spread of the infectious agents. Set the solution boundary to get the virus spreading in the cabin through the air Probability. Analyze the data to find the propagation probability of droplets in a certain range. After obtaining the relevant data, we will study the air circulation system in the cabin of the aircraft, and study how to build a more complete air circulation system in the cabin to reduce the probability of the spread of respiratory infections and viruses in the cabin.

3. Research Program

3.1 Analyzing aerosol transmission

Aerosols are generally colloidal dispersion systems formed by solid or liquid small particles dispersed and suspended in a gaseous medium. The size can be in the range of 0.001 ~ 100 μm . The average person sneezes and coughs can emit 10,000 to 10,000,000 bacterial particles each time. The sizes of various viruses and bacteria in aerosols are very different. Respiratory infectious diseases are

affected by many factors through droplets and air transmission, such as the speed of droplets, the size of droplets, the number of droplets, the characteristics of droplets in different indoor environments, and the temperature and humidity of transmission.

The bacteria studied in this paper is Serratia marcescens, the particle core diameter is $1\,\mu m$, particle density is $1000\,Kg/m^3$, and air density is $1.2\,Kg/m^3$.

3.2 Object of research

The B737-800 was selected as the carrier for the case study of this subject. Its cockpit distribution, escape exits, seat arrangement and approximate model distribution are shown in Figure 1 below.

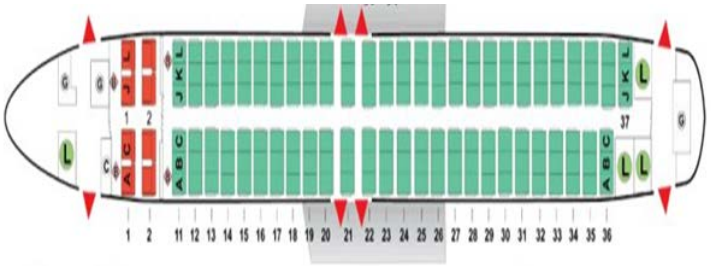

Fig1. Boeing 737-800 cockpit map

3.3 Simulation Modeling

Unigraphics (UG) NX9.0 modeling software was used to simulate a part of the cabin. The upper part of the model is regarded as a three-dimensional cabin model created by cutting the air-conditioning system, as shown in Fig. 2. The top view of the internal structure of the model is shown in Fig. 3.

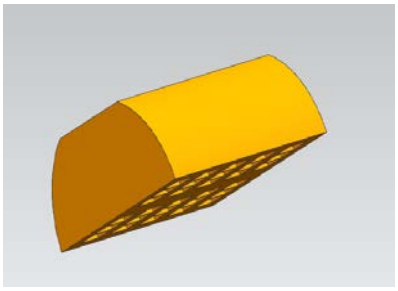

Fig 2 Front view of cabin model

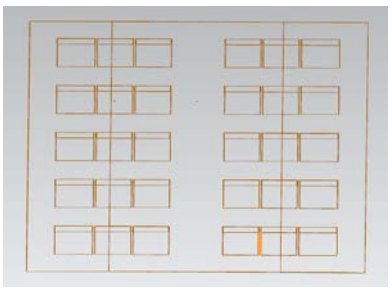

Fig 3 internal structure of the model

In this research, the middle section of the cabin is selected for analysis and research. Each boundary port is named and the grid diagram shown in Figure 4 is divided.

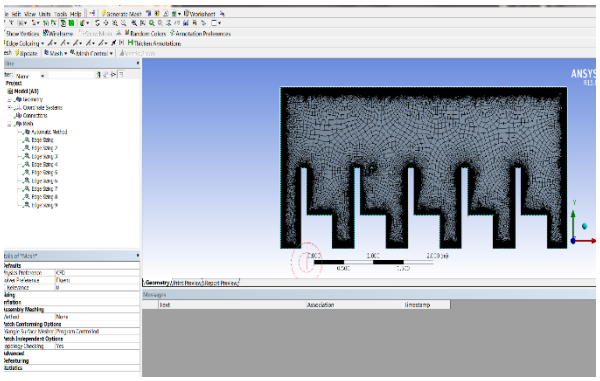

Fig 4 Front view of cabin model

3.4 Boundary (constraint) condition

Boundary conditions are set in this study: coughing or sneezing exhaled viruses are evenly distributed, and the area of transmission in the cabin is the infection zone; assuming that the air flow in the cabin is stable, ignoring the impact of bumps on the spread of germs in the aircraft; temperature is not considered Effects of humidity and humidity on gas diffusion and germ survival; expiratory speeds of 0.3 m/s, 10 m/s, and 40 m/s were used to simulate human breathing, coughing, and sneezing respectively; the carrier's mouth opened when the virus was released The area is $0.02\text{m} \times 0.02\text{m}$. The temperature of the oral droplets produced by coughing in the study was taken from the normal adult body surface temperature 31 $^{\circ}C$; neglecting the state of the droplets in a large particle size, the droplets are approximately considered to be always small particles, and the particle size is assumed to be 1 μm .

4. Results

The volume distribution of droplets in the cabin is shown in Figure 5. It can be seen from the figure that most of the droplets are distributed in the lower part of the cabin, which has a greater impact from the direction of exhalation, and the front part of the cabin is greatly affected. It also shows that in addition to inertia, viral particles are also affected by gravity and the flow field.

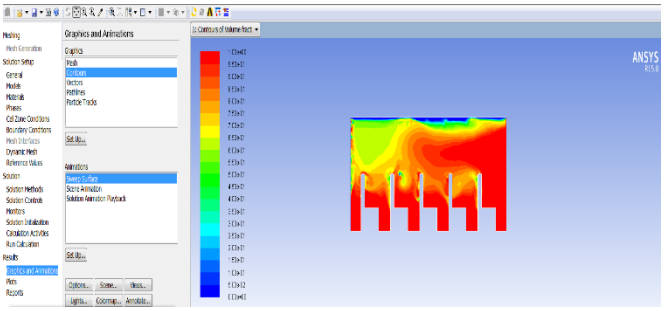

Fig 5 Distribution of droplet water vapor volume in the cabin

The volume distribution of S. marcescens in the cabin is shown in Figure 6. From the figure, it can be seen that the bacteria self-exhaled in the upper part of the cabin and the starting position of the exhalation, as well as the first three rows of seats. This shows that the location of this part is the most prone to bacterial infection. In order to reduce the infection rate, we can develop a better method to block the bacterial infection from this aspect.

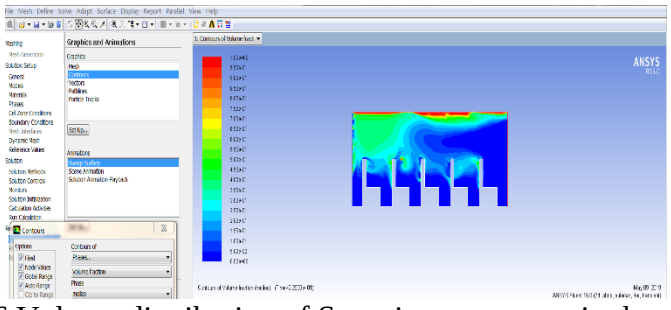

Fig 6 Volume distribution of Serratia marcescens in the cabin

The cloud diagram of the speed distribution of germs is shown in Figure 7. It can be seen from the figure that the speed of bacterial transmission in the vicinity of the infected person can affect at least the passengers in the first three rows of seats nearby. The passengers in this vicinity may be infected by the germs and become Vulnerable people.

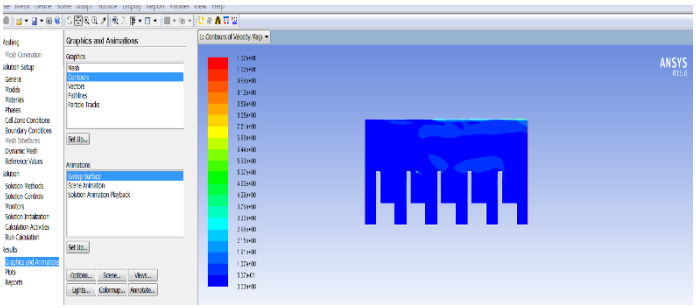

Fig 7 Speed cloud of droplet spread

5. Summary

In this paper, Serratia marcescens is used as the research object of the microbial virus in the cabin to simulate the propagation law of the virus particles in the cabin. Boeing 737-800 was selected to establish the cabin model. The force analysis was performed on the germs to improve the effectiveness. The Euler model in the multiphase flow model was used to perform the fluent analysis. Through CFD simulation analysis, it can be known that the distance of the sprayed bacteria from the human body is related to the indoor temperature and its own speed. Bacteria produced by sneezing, coughing and other movements can move about 1.5m. Once a virus carrier gets on the plane, the three rows of seats around the carrier are vulnerable areas. Through simulation, it can be known that the design of the ventilation system in the cabin design can further improve the air circulation in the cabin, ensure the continuous inflow of fresh air, and reduce or avoid the spread of germs.

Acknowledgements

Nature Fund name: Simulation of typical virus propagation in civil aircraft cabins and emergency strategy research project approval number: U1633123 Application code: F01

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