# *Simulation of Droplet Diffusion in Narrow Passage Space of Cruise Ship*

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***Abstract:*** Through the application of computational fluid dynamics theory and simulation technology to the simulation of the spread of the new crown pneumonia epidemic on cruise ships, two representative and typical simulation models of cruise ship narrow passages and land hotel passages were constructed, and the total release rate was established. The main technical parameters, such as flow interruption intensity, inlet speed, etc., are used as boundary conditions such as flow inlets and outlets, wall boundaries and other factors. Discrete format three-dimensional simulation calculations using adult sneezing droplets spreading in the local space as the scene are studied and calculated. The droplet diffusion distance in the narrow channel can reach up to 6m, which is three times the result of the hotel channel on the shore. The analysis puts forward the conclusion that the risk of droplet diffusion in the narrow channel space of cruise ships is higher than that in the open space.

## 1. Introduction

In this study, the RNG K - ε turbulence model [1] was selected to calculate the concentration field in the process of virus diffusion and propagation by CFD computational fluid dynamics [2]. Because the novel coronavirus pneumonia virus is very special in morphology, weight and style, its transmission route is not completely clear. Therefore, this study takes the droplet of virus as the research object, and uses the common human exhaled CO2 as the characterization material, and establishes aerosol aerosol [3] by Lagrange method. [4] The mathematical model of particle movement is used to simulate[5] and calculate the spread of virus droplets under different wind conditions in cruise ship cabin, narrow channel and Shore Hotel channel, and analyze and compare the spread distance of droplets[6], so as to provide strong technical support for the follow-up effective prevention and control measures.

## 2. Research Model Construction

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## 2.1. Modeling and Parameter Setting of Cruise Narrow Channel

### 2.1.1. Model of Cruise Ship in Narrow Channel

Taking the narrow passage of the Yangtze River Cruise ship as the prototype of the physical model, the inside of the passage is simplified into a simple hexahedron, 10 meters long, 1.2 meters wide, and 2.1 meters high. The door of the room in the passage is closed. There is no window on the opposite side, only windows at both ends of the passage. 0.5 meters in length, 0.5 meters in width, and 1.2 meters in height, a scene where a virus carrier sneezes somewhere in the channel (see the red dot in Figure 2-2) [7][8], using modeling to analyze droplet spread The situation is shown in Figure 2-2.

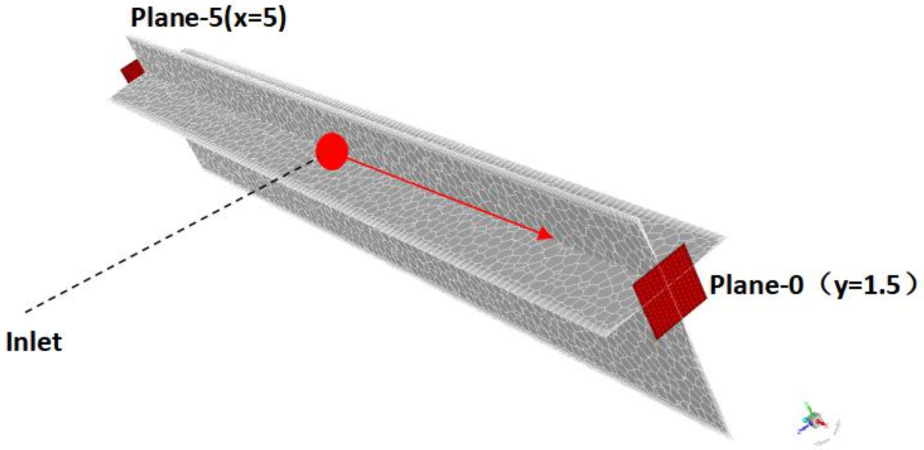

Figure 1: The three-dimensional grid division of the cruise ship's narrow passage model.

### 2.1.2. Parameter Setting

The setting of the boundary conditions directly affects the accuracy of the simulation results. The setting of the boundary conditions of the human mouth as a pollution source has a great influence on the movement trajectory and propagation path of the droplet aerosol. Set the boundary conditions in Table 1.

Table 1: Boundary conditions of cruise ship narrow passage modeling.

| Boundary | Condition[9] |
|---|---|
| Floor, ceiling, surrounding walls, closed doors and windows | Wall, insulated |
| Open window | The inlet velocity is 10 m/s, the turbulence intensity is 6.8%, and the temperature is 21℃ |
| Human body surface | Wall surface, the temperature is constant 36℃ |
| Human mouth | Inlet velocity 80 m/s, turbulence intensity 6.8%, temperature 35℃ |
| Virus droplets (aerosol) | 5μm particles, total release rate 0. 085 μg/s, density 1000 kg/m3 |

## 2.2. Modeling and Parameter Setting with Reference to A Wide Passage

### 2.2.1. Hotel Passage Model

Taking the spacious passage in a hotel on the shore as a physical model prototype, the hotel’s passage is simplified into a simple hexahedron, 10 meters in length, 2.5 meters in width, and 2.6 meters in height. The door of the room opens. The door is 1.9 meters high and 1 meter wide. And there are windows on both sides of the passage, the size of the window is about 1.2 meters long, 1 meter wide and 1.2 meters high. The scene of a certain virus carrier sneezing in the channel, using modeling to analyze the spread of droplets.

Suppose someone sneezes at an instantaneous droplet velocity of 80m/s, and the location is 1.5 meters away from the ground. A circle with a diameter of 30 mm is used as the sneezing velocity entrance in the passage, and the door is set to Pressure-outlet, the value is 1 atmosphere. The Computational Fluid Dynamics software was used for numerical simulation, and the Fluent meshing pre-processing software was used for meshing. [10] The circular entrance surface mesh size is 2 mm, and the calculation domain wall surface mesh size is 80 mm to generate a polyhedral mesh.

### 2.2.2. Parameter Setting

The setting of the boundary conditions [11] directly affects the accuracy of the simulation results. The setting of the boundary conditions of the human mouth as a pollution source has a great influence on the movement trajectory and propagation path of the droplet aerosol. The boundary conditions are set in Table 2.

Table 2: Boundary conditions of hotel passage on shore modeling.

| Boundary | Condition |
|---|---|
| Floor, ceiling, surrounding walls | Wall, insulated |
| Open doors and windows | Inlet velocity 2 m/s, turbulence intensity 6.8%, temperature 21℃ |
| Human body surface | Wall surface, the temperature is constant 36℃ |
| Human mouth | Inlet velocity 80 m/s, turbulence intensity 6.8%, temperature 35℃ |
| Droplet aerosol | 5μm particles, total release rate 0. 085 μg/s, density 1 000 kg/m3 |

## 3. Research on Simulation Results

## 3.1. Calculation Results and Analysis of the Model in the Narrow Passage of the Cruise Ship

At 1s, 3s, and 5s, the X-axis (horizontal direction) virus droplet spreading distance data statistics on the cross-section plane-5 are shown in Table 3.

Table 3: The spread of virus droplets on the horizontal cross section of the cruise ship's narrow passage model at different times.

| Virus droplet volume fraction[13] | Horizontal spreading distance (m) | | |
|---|---|---|---|
| | 1s | 3s | 5s |
| 10% | 0.5 | 0.6 | 1.7 |
| 1% | 2.3 | 3.7 | 6.2 |

In the narrow passage of the cruise ship, a virus carrier sneezed, and the spread of virus droplets at a concentration of 1% at a time of 5s was about 6 meters away.

From the perspective of airflow organization, the local airflow disorder in the narrow channel in this model may lead to the accumulation of virus droplets, contaminate the local area, and cause a higher risk of epidemic transmission.

### 3.2. Calculation Results and Analysis of the Model in the Wide Passage

At 1s, 3s, and 5s, the X-axis (horizontal direction) virus droplet spreading distance data statistics on the cross-section plane-5 are shown in Table 4.

Table 4: The spreading distance of virus droplets on the horizontal cross section of the hotel channel model on the shore at different times.

| Virus droplet volume fraction | Horizontal spreading distance (m) | | |
|---|---|---|---|
| | 1s | 3s | 5s |
| 10% | 0.5 | 0.7 | 0.8 |
| 1% | 1 | 1.8 | 1.9 |

The horizontal distance of the spread of virus droplets at a concentration of 10% in the hotel ashore is about 1.8 meters at a time of 5s. From the perspective of airflow organization, the diffusion concentration in the channel in this model is generally low, and the droplet concentration decreases more with the increase of distance, indicating that ensuring sufficient spacing is effective to reduce the risk of droplet diffusion to a certain extent.

### 3.3. Comparison and Analysis of the Simulation Calculation Results of the two Models

In the narrow passage model of the cruise ship, the lateral distance of the spread of virus droplets at 1% concentration is about 6 meters at the time of 5s. The horizontal distance of the spread of virus droplets at a concentration of 1% in the hotel building on the shore is about 1.8 meters as far as 5s. See Table 5 for details. It can be seen that under the influence of the cruise ship channel wind, the virus spreads far longer than the static wind channel.

Table 5: Comparison of the spreading distance of virus droplets between cruise ship and hotel channel models.

| Virus droplet volume fraction Diffusion distance (m) | | Virus droplet volume fraction Diffusion distance (m) | |
|---|---|---|---|
| | | Cruise ship narrow passage model (m) | hotel passage model (m) |
| 1s | 10% | 0.5 | 0.5 |
| | 1% | 2.3 | 1 |
| 3s | 10% | 0.6 | 0.7 |
| | 1% | 3.7 | 1.8 |
| 5s | 10% | 1.7 | 0.8 |
| | 1% | 6.2 | 1.9 |

From the perspective of airflow organization, local airflow disturbances in the narrow passages of cruise ships may lead to the accumulation of virus droplets, contaminate the local area, and cause a higher risk of epidemic transmission. Compared with the concentration in the narrow passages of cruise ships (mostly around 6%), the diffusion concentration in the spacious passages of shore hotels is generally lower (mostly below 2%), and the droplet concentration decreases with the increase of distance, indicating that the guarantee is sufficient To a certain extent, the spacing is effective in reducing the risk of droplet spread.

Under the condition that the doors and windows are opened as much as possible, the wind speed at the entrance of the spacious passage is lower than the wind speed in the narrow passage of the cruise ship, and the droplet diffusion is relatively regular; while the air vortex and disturbance[14] caused by the narrow passage in the cruise ship are more harmful. Large, resulting in turbulent flow of local air organization, long distances of virus droplets spread under channel wind conditions[15], high risk of virus droplets spreading, which is not conducive to epidemic prevention and control.

## 4. Conclusions

In the narrow passages of cruise ships, the maximum spread of virus droplets at a concentration of 1% in 5s is about 6 meters, which is three times the spread distance of the passages in hotels onshore. The risk of virus transmission on cruise ships is significantly greater than that on land. Gravity plays a major role in the spread of droplets, and the risk of spreading the virus on cruise ships is significantly greater than the risk of spreading the virus on land. In the case of the same inlet wind speed, the aisle of the hotel on the shore is relatively spacious due to the lateral airflow, and the linear propagation distance is relatively small; while the wind direction and speed of the channel wind in the narrow passage of the cruise ship play a major role, and the linear propagation distance increases.

Airflow vortex and disturbance caused by narrow passages in cruise ships have greater adverse effects, resulting in turbulent flow of local airflow and high risk of virus droplets spreading in passage wind conditions, which is not conducive to epidemic prevention and control.

As the linear distance increases, the droplet concentration decreases more, and ensuring a sufficient distance is effective to reduce the risk of droplet diffusion to a certain extent..

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