Comparative Study of Two Pressure Difference Control Methods in Contaminated Rooms Based on CFD Simulation

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Abstract. The pressure difference control is realized by the pressure drop when the room infiltration air passes through the room opening such as the door crack, and its effect is determined by the room air distribution and the geometric characteristics of the opening. In this paper, two kinds of air distribution are used to achieve pressure difference control for two kinds of polluted room and corridor layout. With building the contaminated room models, CFD simulation technology was used to simulate the pressure difference between the room and the corridor and the directional airflow through the opening under different room opening forms, and on this basis, the role and applicable characteristics of the two ways of pollutant control are discussed. The simulation results show that if the room is well sealed, a small amount of infiltration air volume can produce enough pressure difference through the crack of the door, but it is easy to cause the diffusion of pollutants when the door is opened; when the opening is set on the wall, a large amount of infiltration air is needed to produce enough pressure difference, but it is more beneficial to control the diffusion of pollutants when the door is opened.

Keywords: Pressure Control, Infiltration Air, CFD, Air distribution.

1 Introduction

Pressure difference control technology is an effective control means to prevent pollutants from diffusing with airborne transmission between areas with different cleanliness levels and pollution levels.[1,2] These areas maintain an orderly pressure difference distribution, and rooms with pollution sources maintain a pressure difference lower than surrounding environment, that is, negative pressure. Negative pressure is usually achieved by which the supply air volume in the polluted room is less than exhaust air volume, and difference between supply and exhaust air volume is made up by the infiltration air volume. The pressure difference between the inside and the outside of the room is realized by the pressure drop when the permeated air encounters resistance through the gap between the door and the window. The differential pressure value is

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determined in conjunction with the amount of infiltration air and the geometric characteristics of the opening.[3]

In engineering practice, the polluted room was always arranged with corridor,[4,5] and the arrangement of air distribution can adopt two forms: (1)The rooms and corridors were provided with air supply and exhaust outlets. The infiltration air volume was the difference between the air supply and exhaust in the room. The infiltration air was generated by the pressure drop through the door gap to realize the pressure difference between the inside and outside of the room. (2) An opening was arrange on the wall between room and corridor, the exhaust outlet was arranged in that room, the air supply outlet was arrange in the corridor, so the infiltration air volume was the exhaust air volume of the room, and the pressure drop generated by the infiltration air through the opening ,which realized the pressure difference between the inside and the outside of the room. In this paper, two kinds of air distribution were simulated by CFD numerical simulation to test the effectiveness of negative pressure control under the two arrangements.[6]

2 Model and Simulation

The contaminated room was 6.7 m long, 5 m wide and 5 m high. The corridor was 2m long, 5m wide and 5 m high. The door was 1.9 m long, 2 m high and 0.04 m thick. The door had two opposite doors.

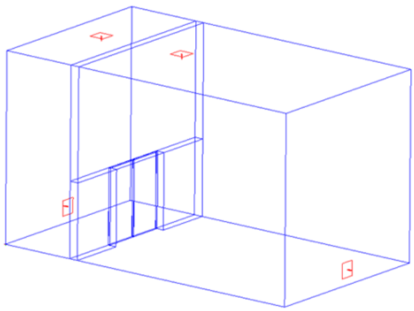

Fig. 1. Model 1

2.1 Model 1

As shown in the Fig.1., the rooms and corridors were provided with air supply and exhaust outlets respectively, and the size of the air outlet was 400 mm * 400 mm. The air supply volume in the room was set as per 6ACH, so the air supply volume in the room was 0.279m^3/s, and the air supply outlet speed in the room was 1.747 m/s. The exhaust air volume of the room was set as 1.1 times of the air supply volume, so the exhaust air volume was 0.307m^3/s, and the exhaust speed was 1.92m/s. The infiltration air volume was the difference between the air supply and exhaust of the room,

$0.028 m^3/s$. The exhaust air volume of the corridor was set as 2ACH, so the exhaust air volume of the corridor was $0.0281 m^3/s$, and the exhaust speed was 0.176m/s. The air supply volume of the corridor was the exhaust volume of the corridor plus the infiltration volume, which was$0.0558 m^3/s$, and the air supply velocity was 0.349 m/s. The two ends of the corridor were connected with the atmosphere and were set as constant pressure ports in the model.

(1)There were 5 door cracks in the opposite-opening door, and the width of the door crack was set as 5mm. As shown in the figure, the simulation results showed that a directional airflow through the door crack was formed from the corridor to the room. However, the room pressure was -2.965Pa, the corridor was 0.004Pa, and the pressure difference between inside and outside the room was just about 3Pa and insufficient, which was not safe to pollutant control.

(2)In order to more effectively form the pressure difference between the inside and outside of the room, the middle door crack and the top door crack were sealed by sealing strips, and only the two sides and the bottom door crack were considered.

As shown in the Fig.2., the simulation results showed that a directional airflow with higher velocity from the corridor to the room through the door crack was formed. The simulated results showed that the room pressure was -6.740Pa, the corridor pressure was 0.022 Pa, and the pressure difference between the room and the corridor was about 6.962Pa, which increased and basically met the control requirements when the door was closed.

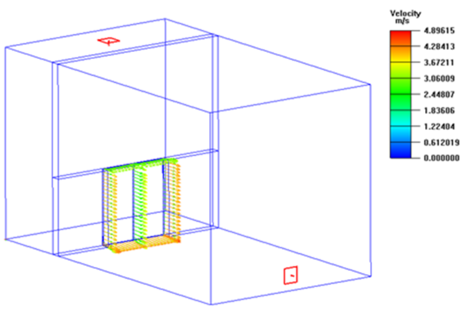

Fig. 2. air velocity distribution at the door crack in Model 1

(3) In order to increase the pressure difference between indoor and outdoor air , the infiltration air volume was increased by increase the exhaust air volume of the room and the supply air volume of the corridor. So the exhaust air velocity of the room was 2.0m/s, the supply air velocity was 1.747m/s, the supply air velocity of the corridor was 0. 436m/s, the exhaust air velocity was 0. 176m/s. The difference between the supply air volume and the exhaust air volume was increased to 15%, and the infiltration air volume increased. The simulated results showed that: the room pressure was -10.369 Pa, the corridor was 0.014 Pa, and the pressure difference was about -10 Pa.

In this model, the geometric size of the door crack was simplified. In the certain project, the permeability characteristics of the door should be provided by the manufacturer or determined by simulation and experiment. Based on the permeability characteristics of the door, the permeability air volume, which was the air supply and exhaust difference, was determined.

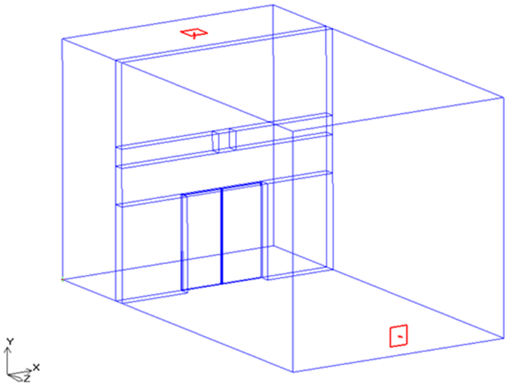

Fig. 3. Model 2

2.2 Model 2

An opening between the room and the corridor was set on the wall as shown in Fig.3 . The size of the opening in the wall was much larger than that of the door crack, so a large infiltration wind was needed to create a sufficient pressure difference. If the air outlet arrangement of Model 1 was also adopted, the exhaust air volume of the room and the air supply volume of the corridor were too large. Therefore, only the exhaust outlet was set in the room, and the air supply outlet was set in the corridor. The length and width of the air outlet were still 400 mm*400 mm. Same as Model 1, the room exhaust air volume and the corridor supply air volume which set as 6ACH were both 0.307 m^3/s, and the air outlet velocity was 1.92 m/s. The infiltration air volume was the room exhaust air volume, which was much larger than that of Model 1. Consistent with Model 1, Only the left, right and lower door cracks were considered, and the width of the door crack was 5mm.

(1) The opening size was set as 400 mm * 400 mm. As simulation results, room Pressure was -4.483 Pa, and the corridor was -0.001Pa. As shown in the Fig.4, the infiltration wind entered the room from the corridor through the opening in the wall and the crack in the door to form a directional airflow, which effectively controlled the diffusion of room pollutants.

(2) In order to further improve the pressure difference between inside and outside of the room, the opening size was set to 350 mm * 350 mm. The simulation results showed that the room pressure was-6.657 Pa, the corridor pressurewas-0.002 Pa, and the pressure difference between inside and outside the room was 6.655 Pa. Fig.5 was the streamline figure of the air supply outlet in the corridor. As showed in Fig.5, the streamline started from the air supply outlet and entered the room through the opening in the wall.

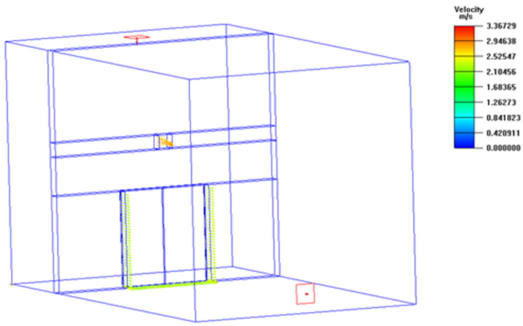

Fig. 4. Air velocity distribution at the door crack in Model 2

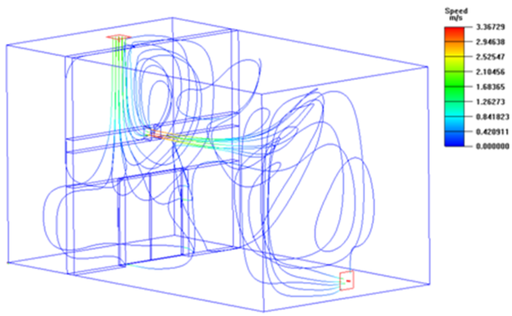

Fig. 5. The streamline distribution of the air supply outlet in Model 2

(3) As the wall opening reduced to 300 * 300, room pressure turned to-10.529 Pa and corridor pressure turned to -0.001Pa. It could be seen that the pressure difference was related to the size of the room opening. Under the same infiltration air volume, the opening size decreased and the pressure difference increased.

3 Discussion

(1) In the Model 1, the infiltration air volume was 0.028 m^3/s and the pressure difference between the inside and outside of the room was 6.96 Pa when the infiltration air volume passed through the crack of the door. In the Model 2, the infiltration air volume was the exhaust air volume of the room, which was 0.307 m^3/s and the pressure difference between the inside and outside of the room was 6.65 Pa. The first model room and the corridor were only connected by the crack of the door, so the door sealing were high and the small infiltration air volume could produce enough pressure difference. The second model room and the corridor were provided with openings, the opening area were large, and when the infiltration air volume were large, enough pressure difference could be formed through the openings on the wall.

(2) In the Model 1, the air supply outlet and the air exhaust outlet were arranged inside and outside the room, which was beneficial to forming a reasonable air distribution by adjusting the positions of the air supply outlet and the air exhaust outlet[7], so as to better remove pollutants. However, the infiltration air volume was small, and the requirement for the sealing of the door crack was high. When the door was opened, the average air velocity on the cross section of opened door was only 0.007 m/s, and it was difficult to control the air flow in and out as the door opened, which was easy to cause pollutant diffusion.[7]

The second model room was provided with an exhaust outlet, and the corridor was provided with an air supply outlet, which was simple and easy to manage. In addition, the infiltration air volume was equal to the air supply volume, which was large enough. When the door was opened, the wind speed on the door section was significantly increased, which could better control the diffusion of pollutants through the opening section.[8]

4 Conclusion

(1)When the pressure difference is formed through the door crack, a small amount of infiltration air volume can form enough pressure difference, but the room and corridor should be equipped with air supply outlet and exhaust outlet at the same time to accurately control the air supply and exhaust volume and ensure the formation of pressure difference. The infiltration air volume is small, the pressure difference formed is unstable, and the requirement for the tightness of the door is high.

(2) The pressure difference is formed through the opening on the wall. If the opening size is large, sufficient pressure difference should be formed and the infiltration air volume is large. The air supply outlet can be set in the corridor and the air exhaust outlet can be set in the room. The infiltration air volume is large, the formed pressure difference is stable, the air outlets are few, and the control is relatively easy.

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