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Fire Simulation of Atrium Building Based on FLUENT

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Abstract: Atrium buildings can improve the air quality, good lighting conditions and beautiful appearance of indoor spaces, especially in large-scale comprehensive shopping plazas and other buildings in our country. However, shopping plazas are usually densely packed with combustible materials and have a large fire hazard. Moreover, the atrium building structure is complicated and the population is relatively concentrated. Once a fire occurs, the fire smoke will rapidly spread along the atrium space, making the fire situation even more serious. Some of the atrium buildings are connected to the surrounding areas. In case of fire, smoke will quickly fill the entire atrium space and easily spread to adjacent buildings [1-3]. At present, some regulations on smoke control and evacuation of people in atrium buildings have been formulated. However, some regulations are too single and may not be fully applicable to various architectural spaces. It is necessary to conduct in-depth research on relevant fields so as to continuously update and perfect relevant regulations and standards. Therefore, it is an urgent task to study the smoke spreading process, personnel evacuation characteristics and personnel evacuation countermeasures in the atrium building.

Keywords: Atrium buildings, Flue gas temperature, Concentration of CO, FLUENT.

1. INTRODUCTION

Taking the atrium of a large shopping plaza in Guangzhou as an example, this paper designs different fire scenes of atrium buildings and carries out numerical simulation analysis on smoke exhaust scheme of atrium by using Fluent and considering the two factors of fire source position and air supply position. It provides a reference for the fire-fighting performance-based design of smoke control and extraction systems in large-space atrium buildings.

1.1 Fire simulation scene setting.

Based on an engineering example of an atrium shopping plaza in Guangzhou, as shown in figure 1, the plane size of the atrium is 60m from east to west, 36m from north to south, and 35.4 m in height. The fire prevention division of the atrium shopping plaza has the following characteristics: firewall and special fire curtain division are adopted; In the atrium corridor area, some corridor areas will be incorporated into the adjacent shop areas and merged into a fire prevention zone, while the other part of the area will be divided into separate fire prevention zones of the atrium. Premium fire shutters are set up between corridors and atria on each floor, while the boundary between shops divided into independent fire zones and atria is set up with class b fire doors or premium fire shutters that can be automatically closed according to the specification requirements.

1.2 Grid division.

As shown in figure 2, the model space grid is lm in size, and the grids near the fire source, the air supply port and the smoke exhaust port are locally encrypted, with a total grid number of about 300,000. There are five mechanical smoke exhaust ports, which are evenly distributed on one side of the top of the atrium. After the atrium is isolated, the wind will still be supplemented through the gap or air supply opening at the roller blind. Therefore, this paper assumes that the air supply opening will adopt natural air supply. In order to simplify the calculation, there are two natural air inlets at the bottom of the atrium. The air inlets are located on the east and west sides and are 4x2m in size.

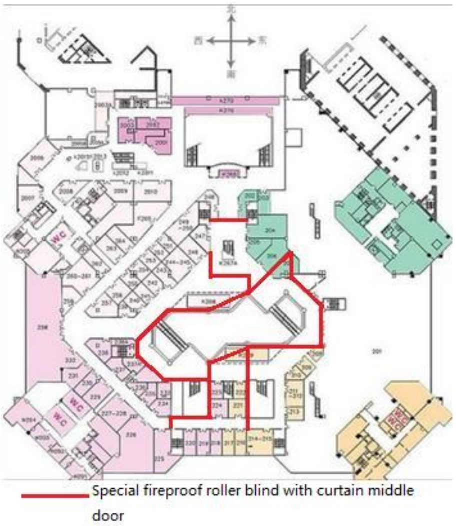

Figure 1.

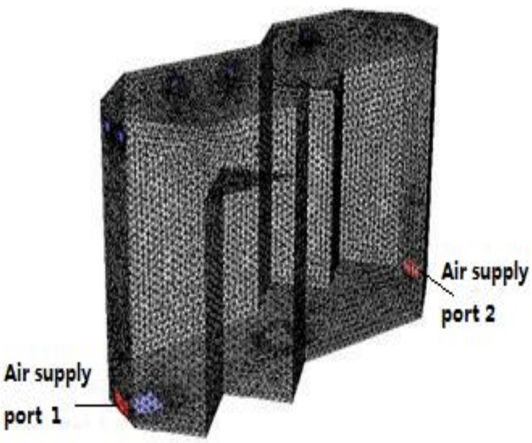

Figure 2.

The ignition source is set as steady state fire, and the combustible gas is composed of CO and CH_4 in a volume ratio of 6. There are two fire sources in the atrium, which are located in the center of the bottom of the atrium and the west corner of the atrium. The size of the fire source is 4mx4m and the power of the fire source is about 20 MW. The influence of the internal spraying system of the building is not considered for the time being. When a fire broke out inside the central court, this paper assumes that the fire curtain of each floor adjacent to the atrium will be lowered in time. When estimating the smoke exhaust volume in the atrium, the calculation formula provided by NFPA92B was used to calculate the wind speed of each smoke exhaust fan to be about 8m/s. The ambient temperature is 300k, assuming both the wall and the ground are insulated. This paper sets up three fire scenarios to simulate respectively:
Scene 1: the ignition source is located in the center of the atrium bottom;
Scene 2: the ignition source is located at the west corner of the atrium (considering the effect of natural wind supplement, the ignition source is specially located near the wall air supplement on the west side of the atrium);
Scene 3: the positions of the two air inlets are shifted 8m upward, and the fire source is still located in the corner of the atrium. The position is consistent with scene 2.

1.3 Mathematical model.

Based on the finite volume method, this paper constructs a mathematical model by Fluent. The combustion model uses partial premixed combustion models [4] in Fluent.

2. SIMULATION RESULTS AND ANALYSIS

In this paper, the numerical simulation of this atrium fire is studied by selecting temperature field, CO concentration of flue gas and velocity field of flue gas. According to the calculation results, when t=300s, the fire is in the stage of rapid development. When t=900s, the height of the flue gas layer reaches a steady state and meets the requirements for safe evacuation time.

2.1 Flue gas temperature.

The vertical central axis passing through the atrium space is taken as a cross section, and the air inlets are positioned on the left and right sides. The flue gas layer temperature distribution of the three scenarios when the fire occurs for 300s and 900s is obtained, as shown in figure3-8. Comparing scene1 and scene2, it can be seen that in the early stage of the fire (figure3-figure4), due to the location of the fire source in scene2 close to the air supply port, the fire process of the fire source under the action of air supply is more violent than that under normal circumstances. However, when the fire source is close to the wall, the smoke plume entrainment restriction will reduce the amount of smoke plume entrainment air. Therefore, there is no significant difference between the falling velocity of flue gas layer height and the temperature rise velocity of flue gas under the two scene. At the later stage of the fire (figure6-figure7), due to the fact that the air supplementing effect obtained by the fire source near the air supplementing port is higher than the effect that the smoke plume is restricted by the wall of the fire source, at the later stage of the fire, the smoke temperature in scene2 is obviously higher than that in scene1, and the falling speed of the smoke layer height is also obviously higher.

By comparing scene2 and 3, it can be seen that in the early stage of the fire (figure4-5), the temperature of the fire scene in each part of scene3 was slightly lower than that of scene2, and the high temperature backflow formed at the top of the atrium also weakened. At the later stage of the fire (figure7-figure8), the effect of lowering the fire temperature in scene3 is more obvious because the increase in the position of the air supply port restricts the full combustion of combustible materials and is beneficial to the supplement of outside air, which is helpful to reduce the smoke formation speed. Therefore, it is helpful to lower the temperature of the fire scene to increase the position of the air supply port and keep it away from the fire source.

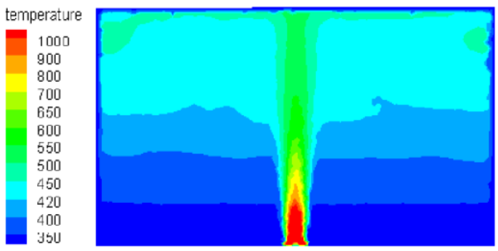

Figure 3. (Scene 1 t=300s)

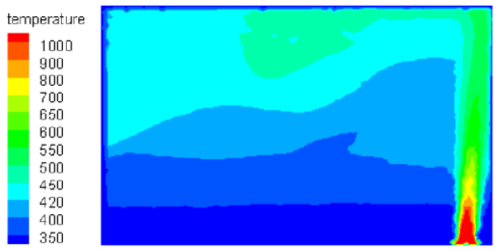

Figure 4. (Scene 2 t=300s)

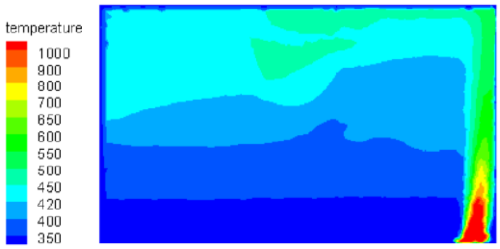

Figure 5. (Scene 3 t=300s)

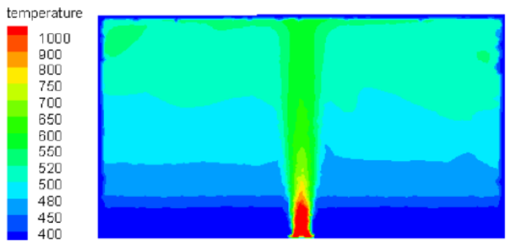

Figure 6. (Scene 1 t=900s)

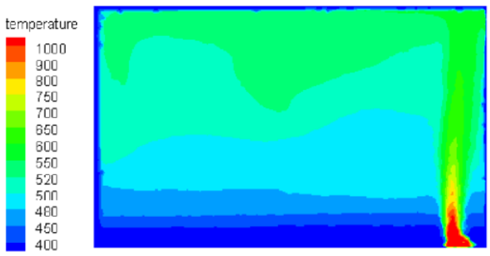

Figure 7. (Scene 2 t=900s)

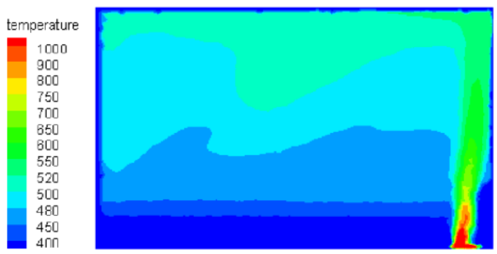

Figure 8. (Scene 3 t=900s)

When t=900s, the flue gas temperature near the atrium floor has already reached 340k 2meters above the ground. If the personnel in the fire scene cannot escape in time, it may lead to casualties. When a fire occurs, the human body's tolerance to the high temperature of smoke is limited. According to related investigations [5], as long as the skin is continuously exposed to flue gas at 71℃ for 60 seconds, it will cause secondary burns to the skin. At 82℃, it will only take 30 seconds.

2.2 Concentration of CO.

Similar to the temperature distribution diagram, the CO concentration distribution of the flue gas layer in the three scenarios when the fire occurs for 300s and 900s is shown in figure9-14. By comparing scenarios 1and2, it can be seen that in the early stage of the fire (figure9-figure10), the higher concentration of CO in scenario1 appeared in the atrium ceiling and near the ground, with a concentration of more than 200ppm, while in scene2 the concentration of CO in the atrium ceiling was more than 500ppm, but the concentration of CO near the ground was smaller. It can be seen that for people on the ground when the mid-court fire occurs, the smoke toxicity hazard when the ignition source is located in the center of the bottom of the atrium is higher than when the ignition source is located in the corner of the atrium. When the ignition source is located in the center of the bottom of the atrium, the uniform distribution of the mechanical smoke exhaust port on the ceiling can effectively exhaust the smoke and reduce the speed of the smoke layer falling at the same time. When the ignition source is located at the corner of the atrium, the ignition source is closer to the air supply port and the ignition source burns more fully, resulting in a decrease in the amount of CO generated. At the same time, due to the distance between some smokes exhaust ports and the ignition source, the effectiveness of the ignition source decreases somewhat. At the later stage of the fire (figure12-figure13), the CO concentrations near the ground in both scenarios were close to 500ppm or more. However, in most spaces, the CO concentrations in scenario1 were still higher than those in scene2. From the above analysis, it can be concluded that under the condition of the same position of the air supply port, the smoke toxicity hazard of the ignition source located in the center of the atrium bottom is higher than that of the ignition source located in the corner of the atrium.

Comparing scene2 and 3, it can be seen that in the early stage of the fire (figure 10-11), the higher the position of the air supply port. The farther away the air supply port is from the fire source, the higher the CO concentration near the ground in the fire scene, but the lower the CO concentration above the atrium. When the fire develops to a stable state (figure13-figure14), no matter near the ground or in the atrium upper space, the CO concentration in scene3 can be found to be higher. The reason analysis is as follows: because the fire source is far away from the air supply port, the oxygen concentration in the vicinity of the fire source in scene3 is relatively low, but in general the oxygen concentration in the atrium interior space is still relatively high, even higher than that in scene2. As the fire progresses, the oxygen content in the atrium becomes less and less, and the combustion of combustible materials becomes less and less sufficient, so that there is a relatively high concentration of CO in a large area, which will easily lead to carbon monoxide poisoning or oxygen-deficient suffocation of evacuees, thus losing their ability to escape.

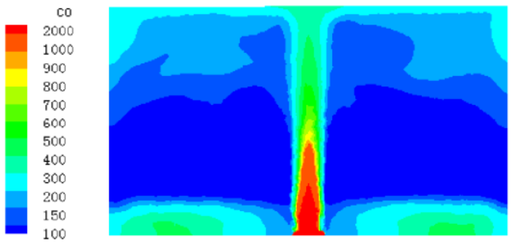

Figure 9. (Scene 1 t=300s)

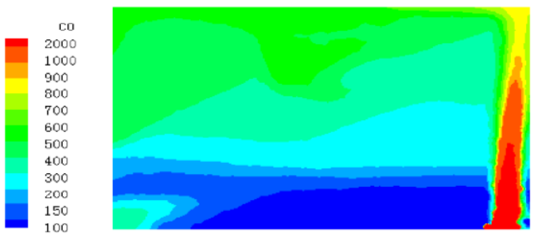

Figure 10. (Scene 2 t=300s)

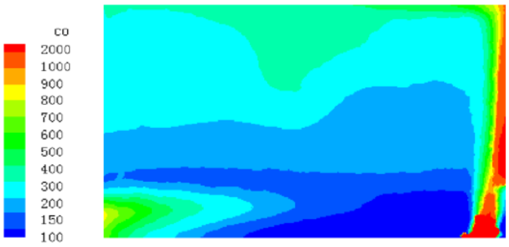

Figure 11. (Scene 3 t=300s)

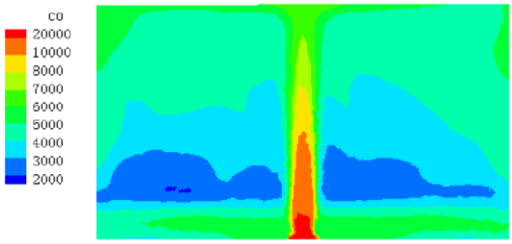

Figure 12. (Scene 1 t=900s)

Figure 13. (Scene 2 t=900s)

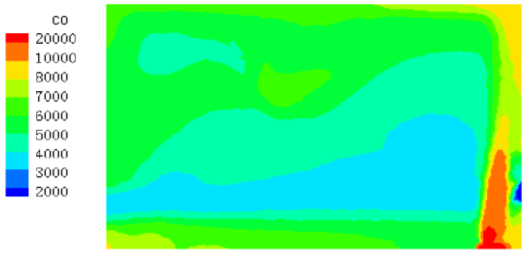

Figure 14. (Scene 3 t=900s)

In addition, high concentrations of CO can be found in the atrium ceiling and far away from the fire source in scene2 and scene3. This shows that when the toxic components of the fire smoke migrate from the vicinity of the fire source to a long distance, the CO concentration does not change much, and can still maintain a high concentration even greater than the concentration in the vicinity of the fire source. Although people are not threatened by serious fire at places far away from the fire source, the threat of smoke toxicity does not necessarily decrease or even become more severe. This situation is consistent with the result that some victims in some building fire accidents have their death positions far away from the fire source.

2.3 Flue gas velocity change caused by position change of air supply port.

The smoke velocity distribution of scene2 and scene3 at 900s of the fire is shown in figure15. In scene2, the fire source is facing the air supply port. Due to the entrance of outside air, the position of cigarette plume plume is deviated to a certain extent. Compared with scene3, smoke plume entrainment in scene2 is relatively small, resulting in a larger amount of smoke plume entrainment and a larger velocity of smoke reaching the ceiling. Because scene2 is more conducive to the development of the plume of hot smoke, it also causes the temperature of the fire scene in scene2 to be higher than scene3. This phenomenon shows that the greater the degree of restriction of smoke layer entrainment above the fire source, the less the air volume of smoke layer entrainment and the smaller the rate of smoke temperature rise.

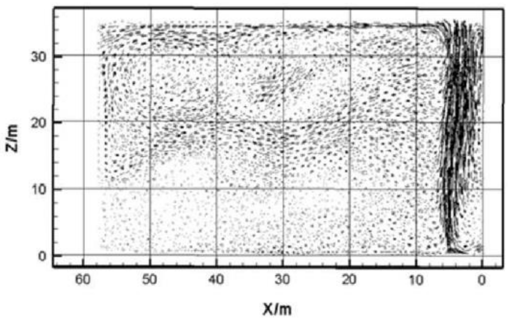

Figure 15 (Scene 2 t=900s)

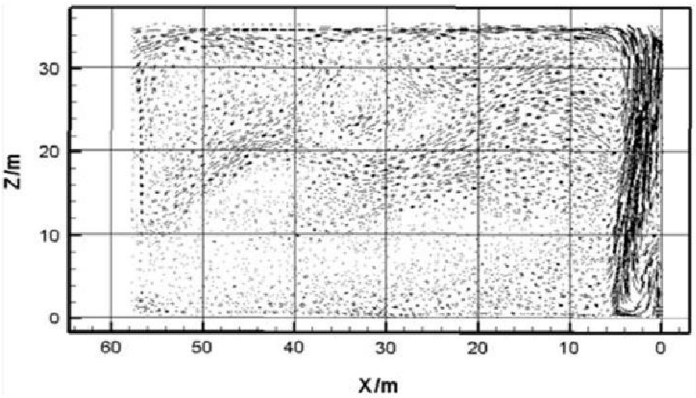

Figure 16 (Scene 3 t=900s)

Smoke velocity vector diagram on atrium section

Based on the above analysis, it can be seen that an appropriate increase in the position of the air supply port is conducive to lowering the fire temperature on the one hand, but on the other hand it may increase the CO concentration in the fire field, which is not conducive to the safe evacuation of personnel in the fire field. From the perspective of personnel safety, the influence of CO concentration is higher than that of flue gas temperature. Therefore, this paper thinks that the safety of scene2 is better than that of scene3.

3. CONCLUSION

The location of the fire source close to the air supply port causes the fire source to catch fire more violently under the action of air supply than under normal circumstances. However, when the fire source is close to the wall, smoke plume entrainment is limited, resulting in a decrease in smoke plume entrainment. Therefore, the location of fire source has little influence on the falling speed of smoke layer and the rising speed of smoke temperature. However, at the later stage of the fire, the smaller the distance between the fire source location and the air supply port, the higher the flue gas temperature. Properly increasing the position of the air supply port is helpful to reduce the temperature of the fire scene on the one hand, and may increase the CO concentration in the fire scene on the other hand, which is not conducive to the safe evacuation of personnel in the fire scene. From the perspective of personnel safety, low air supply is more beneficial to personnel escape.When the toxic components of the fire smoke migrate from the vicinity of the fire source to a long distance, the CO concentration does not change much, and can still maintain a high concentration even greater than the concentration in the vicinity of the fire source. Under the condition of the same position of the air supply port, the smoke toxicity hazard of the ignition source located in the center of the atrium bottom is higher than that of the ignition source located in the corner of the atrium.

The toxicity of smoke at the bottom of the atrium is higher than that of smoke at high temperature. After comprehensive analysis of the fire occurrence process in the three scenes, this paper believes that scene one is the working condition with the greatest potential safety hazard for personnel evacuation, and further research is needed on the safety of personnel evacuation in this scene.

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