Analysis of the influence of open door size on fire smoke diffusion law in protective engineering

Zheli Xing [a], Jinfeng Mao [b], Chaofeng Li [c] and Jin Zhou [d]

PLA University of Science and Technology, Nanjing 210007, China

[a]zheli86@sina.com, [b]maojinfeng628@sina.com, [c] lichaofeng789@hotmail.com, [d]mingmeng.2006@163.com

Abstract

For researching the influence of the area of room door to the smoke distribution in room-corridor geometry fire, based on similar principle to build a model-entity ratio of 1:4 model experiment system, conducted four conditions of model experiment, analyzed the temperature distribution in corridor, investigated the concentrations of CO, CO2, O2 in corridor under different room door area. The results showed that, the temperature in corridor decreased as door area decreased; the concentrations of CO, CO2 increased obviously and the concentrations of O2 descended with the decline of door area; the decline of door area would cause very disadvantageous effect on the evacuation of occupants.

Keywords

protective engineering, area of door, fire, smoke.

1. Introduction

The fire smoke is the general name of the gas and the suspended particles in the fire. It is one of the basic parameters of the fire. After the fire in a short time, the formation of a large number of hot smoke is the main cause of casualties. According to statistics, the number of deaths caused by smoke toxicity accounts for 85% of the total number of deaths [1], and the high temperature flue gas also causes great damage and even the collapse to equipment, facilities and the structure of buildings [2].

Suard et al. [3] used the method of numerical simulation to study the temperature and velocity distribution of gas at the entrance of small scale single chamber. Tlili et al. [4] study the influence of the shape and fire source of the single chamber roof on the height, gas temperature and velocity of the smoke gas in the entrance. The smoke flow model of the small size room and corridor was designed by domestic Yongheng He et al [5] used the FDS fire simulation software. The results show that the experimental simulation and numerical simulation of small size room and corridor gas flow law is the same. Zheli Xing et al.[6] performed the scaled model experiments and investigated the maximum smoke temperature prediction model when protective engineering fire.

Single room and corridor are the basic units of the protection engineering, "room-corridor" structure is a very typical structural style, in which the fire occurred in a single room and people often escape through the corridor the project. Previous studies on the smoke at the entrance of the room were mostly based on a single room, and a single room and corridor model test bench with more close to the actual situation is less. This paper is aimed at the characteristics: the protection engineering space is narrow, the corridor is longer and it cannot open the window and so on. According to the principle of similarity, it builds a "room-corridor" model experimental platform and data acquisition system and analyzes the gas temperature, concentration and other data in order to obtain the effect of door opening size on the smoke diffusion in the corridor of Protective Engineering through the change of single chamber door opening size of experimental conditions.

2. Design and construction of test bench

2.1 Construction of test bench

Test selects a protective engineering of a fire partition as a prototype and consists of a fire room and long passage, the middle is the corridor (size 2m x 3m x 60m), the fire room size is 4.8m x 2.4m x 3m, the room opens a high 2m, wide 0.8m door and has no windows, the corridor is closed near the fire. The model is built by the geometric proportion of 1:4 and is high 0.5m and wide 0.2m, showing in Figure 1. Models used in the main plastic materials to modular connection, can change the height and width of the corridor according to the test requirement. Fire room walls select glass of resistance to high temperature tempered and the top uses thick iron. The module is connected between the fire sealant occlusion models schematic as shown in Figure 2. According to the similarity theory of heat transfer and the key similarity criterion, the corresponding relation between the model fire and the prototype is deduced. The temperature scale of the model and the prototype is 1:1, the time scale is 1:2, and the burning thermal scale is 1:64.

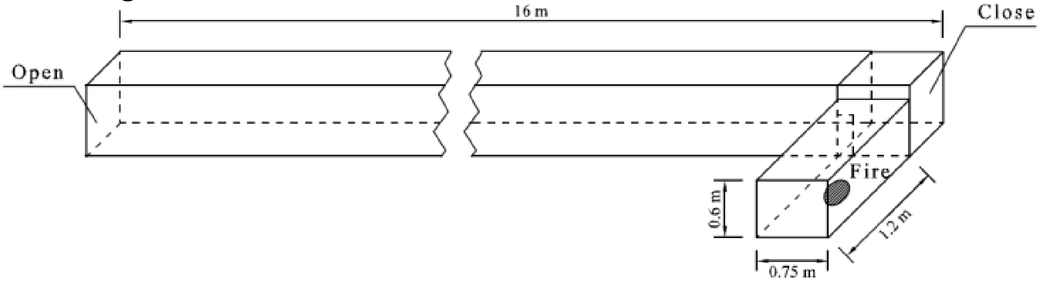

Fig. 1 model test bench size

Fig. 2 Schematic diagram of the model test bench

2.2 Fire source and working case

The fire model test uses n-heptanes as the fuel, with a diameter of 14.1cm circular pan placed 200ml of fuel. Experiments were carried out on 3 working conditions: condition 1 (door open), condition 2(door opened 2 / 3), condition 3 (door opened 1 / 3).

2.3 Data acquisition system and measurement point layout

Thermocouple detect tree is made with the diameter of 0.5 mm K type thermocouple .The thermocouple measurement range is 0 ~ 1300 ℃, measuring accuracy was 0.4%, the response time is 10 s. The temperature data is displayed collection software after the process of temperature acquisition module R-8018BL and RS-485 communication bus.

The carbon monoxide, carbon dioxide and oxygen concentrations are measured at the same time by TESTO 310 smoke analyzer. Oxygen measurement accuracy is 0.2%, the response time is 30 s, the response time of CO and CO_2 are 60 s, the measuring accuracy of CO is 20 PPM (0-400 ppm), 5% (401-2000ppm), 10% (2001-4000 ppm).

As shown in Figure 3, the corridor set up a total of five thermocouples tree (T4-T8) respectively from corridor fire end 0.75m (T4), 3.75m (T5), 6.75m (T6), 10.75m (T7), 14.75m (T8). Each thermocouple tree has six temperature measuring points, at the bottom of the measuring pitch ground 3cm, top measuring pitch roof 2cm, adjacent to the distance of the probe is 14cm. Setting gas analyzer measuring point S1 (5m) in the corridor.

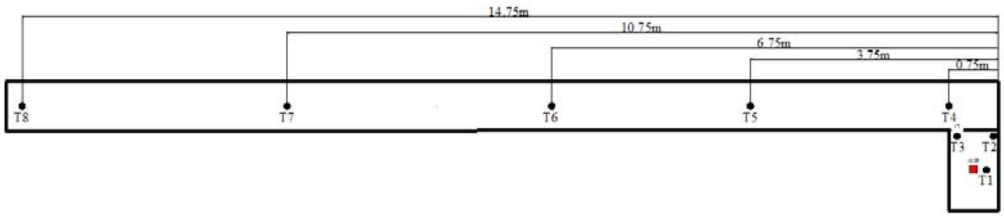

Fig. 3 Schematic diagram of thermocouple

3. Results and discussion

3.1 the influence of the opening size on the temperature distribution

Figure 4 and 5 show that the temperature distribution of the fire room door not fully open and fully opened in T5 and T7 was basically consistent and the overall temperature within the corridor and the maximum temperature of the ceiling decline with the increase in the room door closed part of the and temperature change rate slowed down, indicating that closing fire room door weakens the effects of flue gas of thermal radiation on personnel escape, thus closing house door makes people easier to escape only from the angle of temperature.

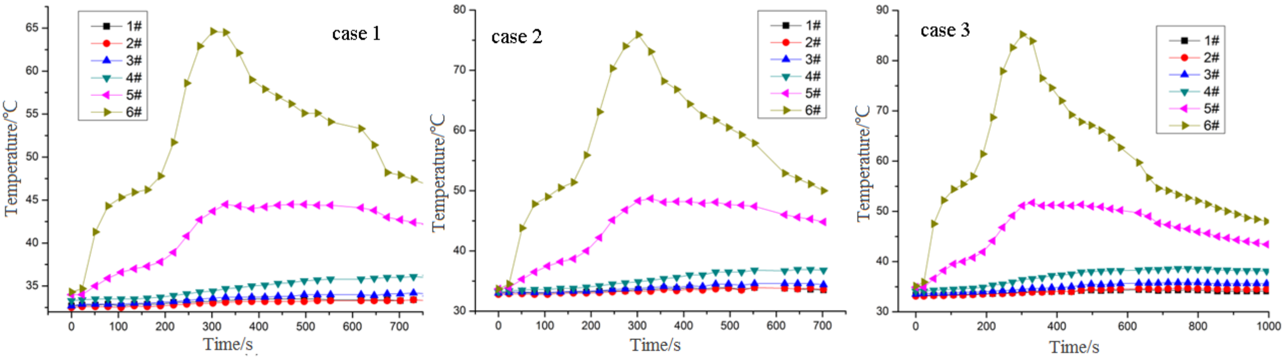

Fig. 4 the temperature distribution of T5 in different size

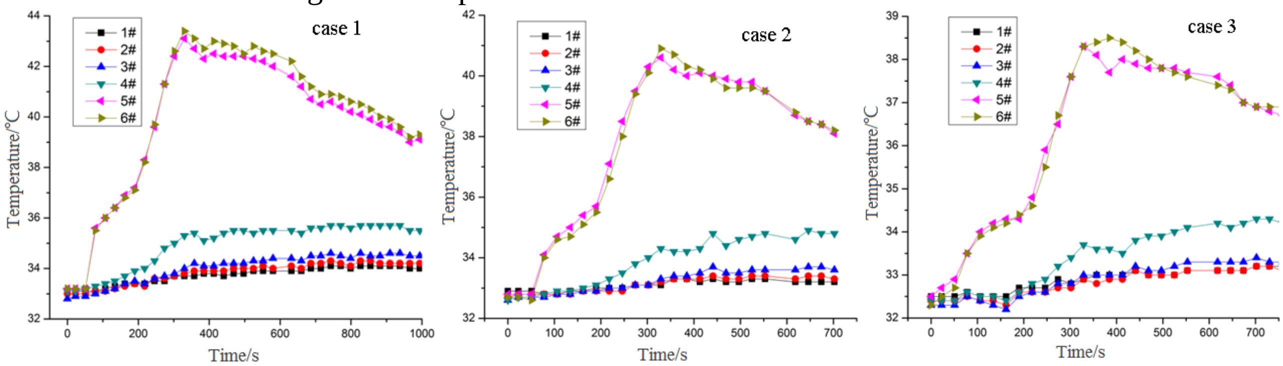

Fig. 5 the temperature distribution of T7 in different size

3.2 The influence of the size of door on the flue gas concentration

By figure 6, the CO concentration under 3 cases is basically the same as that of the time. The peak value of CO is almost the same, but the peak value of CO increases with the decrease of the door opening. The maximum CO concentration of the smoke at the time of case 1 is only 380ppm, rises to 1000ppm in case 2 and finally once again soars to 1600ppm in case 3. The reason is that the size of the open area of the fuel is not enough to burn, so the more open the door area, the more CO. The CO concentration in case 1 did not reach the risk value (600ppm) during the whole fire, however, due to the closure of the door, the fire process CO concentration in case 2 and 3 not only reach the risk value, but also is also earlier to reach the risk with the time for 250s. Therefore, when the people in fire room escape, closing the room door will lead to more fire source CO gas, and thus affect the escape.

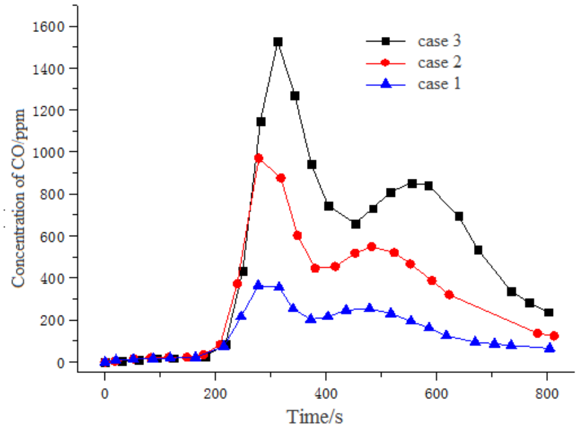

Fig. 6 Influence on CO

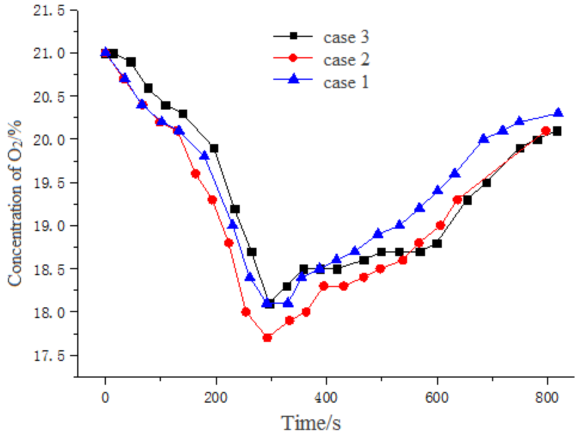

Fig. 7 Effect of different size of O2

The observation of figure 6 and 7 shows that the change trends of O_2 concentration and CO_2 concentration in the flue gas at three different conditions are the same as that of the time, but the minimum and maximum values of O_2 concentration and CO_2 concentration do not increase or decrease with the increase of the opening of the door. Under the three conditions, the minimum of O^2 concentration is 2, and the maximum of CO_2 concentration is 3. The fire generates more CO gas in the condition 2 due to the door to close the 1/3, resulting cooling air intake of the amount of reduction in a single indoor. This promotes that the CO gas in a single chamber with fresh air mixed reaches the source of the fire to produce CO_2 gas and the door was shut down 1/3 with air volume decreased but still be able to make this process for a period of time. This process continues to increase the amount of CO_2 gas generated, resulting in the consumption of oxygen increased, thus the minimum value of O_2 concentration and the maximum value of CO_2 concentration in the figure 7 and 8 are decreased and increased respectively. For case 3, due to the door open only 1/3, fresh air is seriously insufficient, resulting he process of CO gas in the single chamber mixed with fresh air to reach the source to produce CO_2 gas seriously disrupted, at the same time, because the single room door opening is very small, the smoke aggregation in the single room results in a lot of CO emissions.

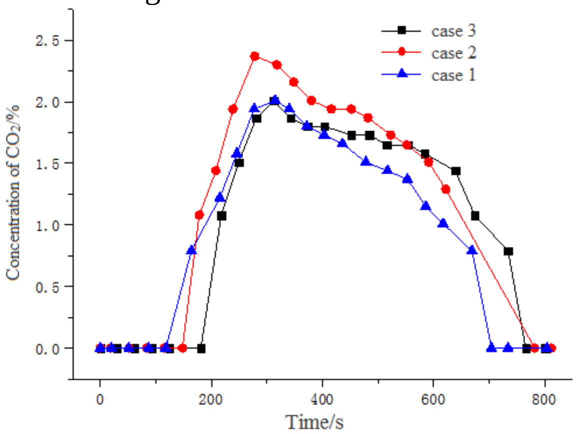

Fig. 8 Effect of different size of CO2

4. Conclusion

When a fire occurs in a single room of the protective engineering, opening the single chamber door has played an inhibitory role to the diffusion of heat to the corridor, however, due to the door opening area reduced leading to the deficiency of air supply, incomplete combustion of the fuel results in CO concentration and CO_2 concentration significantly increased in corridor and O_2 concentration decreased, which has had a very bad effect on the personnel escape. Therefore, the door is better not be closed when a fire occurs in a single room of the protective engineering and the fire room door cannot be completely closed.

References

[1] Alarie, Y. Toxicity of Fire Smoke.Critical Reviews inToxicol.2002, 32(4): 259–289.
[2] Lin Zhi, Guo Jun, Li Qiang. Rules of physical and mechanical damages of high temperature of fire to lining concrete in highway tunnels[J]. Technology of Highway and Transport，2012(6):92-96
[3] S. Suard, A. Koched, H. Pretrel, L. Audouin. Numerical Simulations of Fire-induced Doorway Flows in a Small Scale Enclosure [J]. International Journal of Heat and Mass Transfer, 2015, 81(1): 578-590.
[4] OnsTlili, HatemMhiri, Philippe Bournot. Airflow Induced by a Room Fire: Effect of Roof Shape and Source Location [J]. International Journal of Thermal Sciences, 2015, 90(10): 135-149.
[5] He Yongheng, Liu Zhen, Li Yanna. Simulation study on smoke flow regularity in small size room and corridor[J]. Fire Science and Technology. 2012，31(3): 247-250.
[6] Zheli Xing, Jinfeng Mao, Yuliang Huang, et al. Scaled Experiment Study on Maximum Smoke Temperature along Corridor Subject to a Room Fires[J]. Sustainability. 2015, 7(8): 11190-11212.