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Research on fire test of train compartment based on multi-channel parallel calorimetric system

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Abstract: The multi-channel parallel calorimetric system can ensure the test accuracy in the small-scale fire experiment, and also meet the measurement range of the large-scale fire experiment. Based on the test system of the railway rescue station, the solid and liquid combustibles were used for the real fire test, which were carried out outside the train compartment and inside the train compartment respectively. The real fire test was measured HRR, fire load, top maximum temperature. Through the comparison and analysis of the test data, the results showed that when the fire occurred in the confined space was harmer, so it was very important to do a good job of fire prevention and control in the confined space, especially in the tunnel. By comparing the combustion of solid and liquid, the damage of windows will increase the fire hazard.

1. Introduction

With the development of national economy, China's tunnels have become the most numerous from the point of view of current development, fastest-growing and most complex tunnels in the world. Due to the closeness of its own structure, the conditions of smoke exhaust and heat dissipation were extremely poor, which will cause incalculable damage when the fire started. [1] Heat release rate was an important parameter in fire hazard analysis. It played an important role in fire and affected other fire factors. The heat release rate referred to the heat released by combustibles in a unit time, which was usually obtained by testing the principle of oxygen consumption. [2] In the design of fire protection engineering, it was necessary to determine the design scheme of fire extinguishing device and the flow of fire extinguishing medium according to the heat release rate. Therefore, in order to accurately analyzed the fire risk and determined the fire extinguishing device, it is necessary to have an accurate understanding of the HRR of fire [3].

In the Runehamar tunnel, Haukur Ingason et al [4-5] simulated the full-scale HGV fire experiments and the results showed that different combustibles had different fire growth rates and peak heat release rates also different. In 2016, through FDS numerical simulation, Li Dong and others obtained the conclusion that they paid special attention to the fire protection of key parts of the train.[6] In 2017, Wang Sheng et al. analyzed the influence of train materials on heat release rate through cone calorimeter test, and got the conclusion that increasing the fire resistance of train seat and roof materials can improve the fire safety performance.[7]In 2019, Wang aiwu et al. established the FDS train compartment model and got the conclusion that luggage has a greater impact on the HRR of the compartment fire. [8] Previous studies have analyzed the influencing factors of the HRR of the compartment fire, mostly through FDS numerical simulation or small-scale entity test, and there is no

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comparison between the fire occurred inside and outside the train compartment. So based on the multi-channel parallel HRR calorimetric system of the railway rescue station, [9] this paper established the physical model of the 1:3 entity passenger compartment, analyzed and compared the differences of factors inside and outside the train compartment. The development law of fire in train compartment was studied. It was proposed to select gasoline and tire to represent liquid and solid combustibles for fire test.

2. Measurement system and method

2.1 Measurement system

The measurement system model is 30m in length with a cross-section of $6m \times 6m$. as shown in Figure 2-1. A measuring point is set in the straight pipe section with a length of 8.4m. The measuring point is 5.6m from the upper rectifier grid and 2.8m from the lower rectifier grid. According to the investigation of the existing passenger train size, this paper establishes a simulation passenger train model with the overall dimension of $6m \times 3m \times 2.5m$ based on the container, as shown in Figure 2-2(a), in which the window parameters are $1.3m \times 0.65m$ or $4 \times 0.65m$, and the height is 0.9m. At the same time, the luggage rack is also installed at the height of 1.8m on both sides of the carriage, as shown in Figure 2-2(b). The k-type thermocouples are used to measure the temperature, and the rule of temperature change with time has reached the goal of understanding the fire development characteristics. The distance between thermocouples arranged directly above the fire source is shown in Figure 2-3.



Figure 2-1. The combustion chamber (the bench of railway tunnel rescue station)



(a) Passenger train compartment model (external)



(b) Passenger train compartment model (internal)



Figure2-2. Passenger train compartment model

Figure 2-3. The diagram of temperature measuring point in test system

2.2 Test method

In this paper, 1.5m diameter oil pan and automobile tire were used as combustor respectively, and each

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group of tests were respectively placed inside and outside the train compartment, to compare the experimental phenomenon of combustor burning inside and outside the simulated train compartment and the changes of parameters in the combustion process, and to analyze the difference of combustor burning in the open system and the half open system.

Oxygen molecules are paramagnetic and move towards a strong magnetic field in a non-uniform magnetic field. Therefore, when two gases with different oxygen concentrations (respectively as reference gas and to be measured gas, and the oxygen concentration in the reference gas is known) meet in the magnetic field, there will be a pressure difference between them. [10], the oxygen concentration can be measured by the oxygen analyzer, and then the heat release rate of each branch can be measured by the oxygen consumption method. The working conditions are set as follows:

Table 2-1. Liquid fire experiment condition design					
Condition	Size	Consumption	Location		
A1	1.5	201	Outside the train		
A2	1.5m	20L	Inside the train		
Table 2-2. Solid fire experiment condition design					
Condition	Ν	umber	Location		
B1		Q	Outside the train		
B2		8	Inside the train		

3. Results and analysis

3.1 Result analysis of liquid combustible





(a) Experiment A1 (b)Experiment A2 Figure 3- 1. The comparison of experimental phenomena in experiment A1 and A3

The comparison of experimental phenomena of A1 and A2 is shown in Figure 3-1. It can be seen from the figure that when the liquid combustibles burned in the compartment, the flame was basically controlled in the interior of the compartment, only part of the flame overflows the compartment through the window, and the flame height was far less than the combustion in the large space outside the compartment.





Figure 3-2. comparison of heat release rates of A1 and A2



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The comparison of heat release rate and fire loads of the two experiments is respectively shown in Figure3-2.and Figure3-3. It can be seen that the time from the beginning of combustion to the peak value of heat release rate of experiment A2 is less than that of experiment A1, that is, the fire growth rate of experiment A2 is greater than that of experiment A1, and the peak value of heat release rate of experiment A2 is greater than that of experiment A1, the combustion time and fire load of experiment A1 are greater than that of experiment A2.



Figure 3-4. The comparison of temperature over fire in experiment A1 and A2

The temperature distribution above the fire source in the test bench of the rescue station is shown in Figure 3-4. It can be seen from the figure that in the first 60s of combustion, the temperature above the fire source in the two tests has little difference; in the full development stage, the temperature above the fire source in experiment A1 fluctuates greatly, and the maximum temperature is greater than A2; after 145s, the temperature of experiment A1 and A2 gradually drops to the ambient temperature.

3.2 Result analysis of solid combustibles





(a) experiment B1 (b) experiment B2 Figure 3-5. The comparison of experimental phenomena in experiment B1 and B2

The comparison of experimental phenomena of B1 and B2 is shown in Figure 3-5. It can be seen from the figure that when the solid combustibles burn in the compartment, the flame is basically controlled in the compartment, only part of the flame overflows the compartment through the window, and the flame height is far less than the combustion in the large space outside the compartment.





Figure3-6. comparison of heat release rates of A1 and A2



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According to the experimental results, when the solid combustibles are burned inside and outside the compartment, the comparison of heat release rate and fire load of the two experiments is respectively shown in Figure3-6.and Figure3-7. It can be seen that the time from the beginning of combustion to the peak of heat release rate of experiment B1 is less than that of experiment B2, that is, the fire growth rate of experiment B1 is greater than that of experiment B2; the peak of heat release rate of experiment B1.



Figure 3-8. The comparison of temperature over fire in experiment B1 and B2

The temperature distribution above the fire source in the test bench of the rescue station is shown in Figure 3-8. It can be seen from the figure that after the combustion, the temperature rise speed above the fire source of experiment B1 is greater than experiment B2, and the maximum temperature is greater than B2; in the fire attenuation stage, the temperature decay speed above the fire source of experiment B1 is greater than experiment B2.

4. Conclusion

(1) When the combustible was liquid, by comparing the combustion of liquid combustible inside and outside the train compartment, it could be seen that the heat release rate and fire growth rate of the fire inside the train compartment were significantly higher than that of the fire outside the train compartment. However, the highest temperature in the measurement section and the temperature directly above the fire source are lower than that of the fire outside the train compartment. This is because in the semi closed space of the train compartment, the heat generated by combustion cannot be The heat will be fed back to the surface of the liquid combustibles to accelerate the pyrolysis process of the liquid combustibles and the heat can not be well transferred out of the train compartment, so as to increase the heat release rate and other factors.

(2) When the combustible was solid, it was similar to liquid fire. However, the peak value of the heat release rate of solid combustible was lower than that of liquid combustible, which may be that the flame burns to the outside of the train compartment through the window when the liquid is burning, which indicated that the opening of the window will increase the harm of the fire, so the window material with heat resistance should be selected in the design of the train.

(3) When the combustibles burn in the semi open system, the heat generated by the combustion cannot be discharged from the system in time due to the influence of the space of the semi open system, so as to strengthen the thermal feedback effect on the combustibles, accelerate the pyrolysis process of the combustibles, so as to make the combustion process more intense, resulting in the peak value of the heat release rate, the growth rate of the fire and other factors greater than the open system; at the same time, due to the heat The quantity can't transfer out of the train compartment well, so the temperature of the fire source directly above the rescue station and the temperature of the measurement section of the smoke exhaust duct are lower than the fire of the open system. This also showed that when the fire occurs in the confined space, the degree of harm is greater. Therefore, it is very important to do a good job of fire prevention and control in the confined space, especially in the tunnel.

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