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Smoke Flowing Experiments In Case Of Fire In Running Passenger Train

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Abstract

Passenger train fires are rare, but can lead to serious consequences. During passenger train fire, the smoke is the main cause of deaths because of the poison of the material emission. The small-scale experiments of sleeping carriage fire safety have been performed to investigate the smoke flowing in running passenger train. The smoke is recorded simultaneously from the fire starting to extinguish with digital video camera. The speed field of the running train is simulated in combustion wind tunnel of the State Key Lab of Fire Science, University of Science and Technology of China. Sixteen Nickel-chrome N_iS_i armored thermocouples are arranged to measure temperature gradient in horizontal and vertical directions in the model carriage. The temperature data are obtained by means of real time signal process system consisting of a PC, A/D board, and multi-channel data gathering board. A stainless bowl with the diameter of 10 cm and the height of 7cm, or a cylinder vessel with the diameter of 12 cm, is placed in the front or the middle of the model carriage as the combustion vessel. The fire smoking properties and the variation of the temperature field in the sleeping carriage are analyzed. The passenger train fire safety is also presented. It provides the preliminary study for improving the passenger train fire safety and carrying out full-scale experiment in China.

1. Introduction

Well known to all, it is very serious when a fire happens in the running passenger cars, and the fire will cause great damage and casualties because heat and smoke from the fire diffuse the whole carriage very quickly. Therefore, a few countries, such as Japan, France, U.S.A., Russian, and German, have devoted much attention to the study of carriage fire prevention [1]. A great of work has been done on the fire accident investigation, the fire experiment in the cars, the technology of fire prevention and extinguish in the

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train and tunnel, and passenger evacuation at the fire emergency in the countries [2-6]. The uses of these positive results in the practice have had got good effects.

The fire danger mainly comes from heat, smoke and short-of-oxygen. During the course of fire, the heat consists of convective heat and radiation heat, and the smoke consists of the full-burned production (e.g. CO_2, H_2O) and the incomplete-burned production (e.g. CO, sulphide, and chloride). Part of them is poisonous and corrosive and part of them is in the form of granule. At present, with the wide use of new synthetic material in decoration, the smoke is the main cause of deaths because of its poison. In addition, the moving smoke from fire with high temperature and incomplete-burned granules spreads very quickly, which makes the fire extend more easily. It is the reason why the author studies the occurrence, properties and flowing law of fire smoke in passenger trains.

2. Experimental

In the experiment, a 1/5 small-scale model of YW_{22} type carriage [7] is selected as an example. The speed field of the running train is simulated by the wind provided in the combustion wind tunnel [8] of the State Key Lab of Fire Science, USTC. Because of the limitation of experiment condition and the lack-of-finance, only the temperature fields are measured and the flowing-smoke pictures are taken in the simulated car.

2.1 Combustion wind tunnel

The combustion wind tunnel, where the experiment is done, is divided into five segments: experiment segment, shrinking segment, stable segment, heating segment and motive-power segment. The net size of experiment segment is B×H×L=1.8m×1.8m×6m. Four heatproof windows are set up at the both sides of experiment segment for observing experiment (see Fig.1). The wind speed provided by the wind tunnel in blowing can range from 0 m/s to 15 m/s. The smoke is discharged into the combustion hall outside and then into atmosphere through skylights.

Figure 1. Combustion wind tunnel

2.2 The simulated carriage

A 1/5 small-scale model of YW_{22} type carriage, which is shown in Fig.2, is made, and put in the experiment segment of the wind tunnel. In order to observe and take pictures of flowing smoke, four pieces of glass are installed at one side of the model carriage.

Figure 2. Small-scale model of YW_{22} type carriage

2.3 The fire source

The mixture of 120 ml gasoline (to raise the temperature) and 30 ml diesel (to increase smoke dense) are selected as fuel. In addition, 500 ml net diesel and 300 ml net gasoline are also selected as reference. The combustion vessel is a stainless bowl whose diameter is 10 cm and height is 7 cm, or a cylinder vessel with the diameter of 12 cm, which is placed in the front or the middle of the model carriage.

2.4Gathering and processing of temperature data

Sixteen Nickel-Chrome N_iS_i armored thermocouples are planned in the model carriage to measure temperature gradient in horizontal and vertical directions (see Fig.3). Our multi-channel data gathering system consists of a PC, A/D board, and multi-channel data gathering board, which can record the output voltage-signals in real-time (see Fig.4). The gathering velocity per channel of the data gathering system may be selected in 60 times per second. The amplified times of the voltage signals in 100 times. The gathering voltage-signals are transferred into the temperature data by using the relation between voltage and temperature and then the temperature data are saved in the computer.

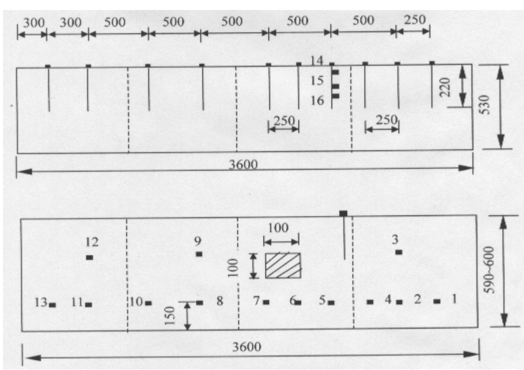

Figure 4. Horizontal and vertical-section of YW_{22} type model car

2.5 Real-recording of the smoke

The smoke is recorded from the fire started to extinguish with JVC GR-DV1 digital video camera. For analysis of the data and processing the flowing smoke easily, the .avi files are transferred to .mpeg files with a high-performance computer.

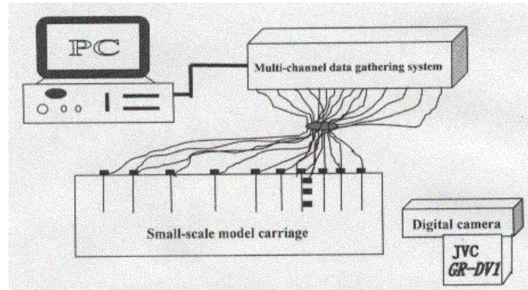

Figure 4. Measuring devices and instruments

3. Results

During the experiment, the wind speed provided by the wind tunnel is 0.6 m/s. According to different fire source position and the firepower, and close-or-open condition of both the front and back door, the temperature fields are measured and the pictures of flowing smoke are taken.

3.1 Experimental Result On The State For Fixing Fire Source Location And Changing Fire Intensity

The fire source is set on the floor in the second room of sleeping carriage near the front door. Diesel, gasoline, and the mixture of diesel and gasoline are selected as examples respectively. Time is recorded at the fire start. The time-temperature curves are shown in Fig.5-Fig.8 (similar curves omitted).

At first the time-temperature curves raise rapidly, and then become gently. The higher the curve is, the nearer the distance from the fire source is. The curves also show that the temperature of the upper in the car is higher than that of the lower. The observed flowing smoke is as the follows: when the fuel begin to burn with both doors opened, the smoke goes upward rapidly because of buoyancy and moves backward quickly because of inertia. When the smoke accumulates at the top of the car, a little of smoke has diffused from both of the doors. The smoke forms a layer in the top of the carriage. When the bottom of the layer becomes lower than the lintels of the doors, a lot of smoke spreads out quickly. The smoke layer can be seen clearly, and their thicknesses keep unchanged in a certain time. In the back door the smoke counter-flows occurs in a long time. The smoke pictures are attached behind. Fig.11 is that the fire source is placed in the front, and Fig.12 is in the middle.

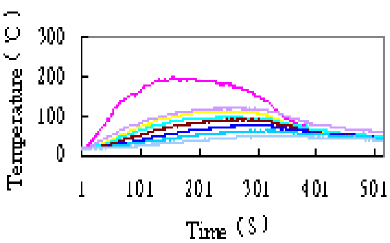

Figure 5. Temperature-time curve with 500 ml diesel in both closed doors

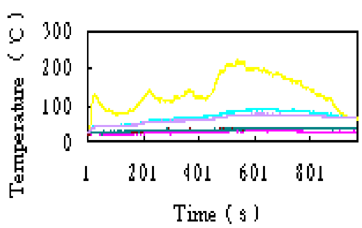

Figure 6. Temperature-time curve with a mixture of 120 ml gasoline and 30 ml diesel in both opened doors

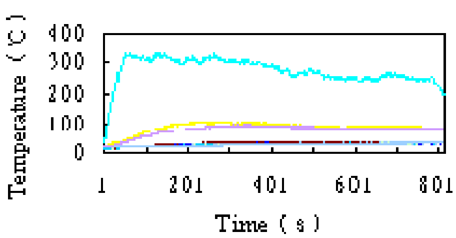

Figure 7. Temperature-time curve with a mixture of 120 ml gasoline and 30 ml diesel in both opened doors

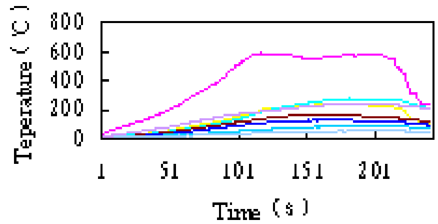

Figure 8. Temperature-time curve with a mixture of 120 ml gasoline and 30 ml diesel in both opened doors

3.2 Experimental Result On The State For Fixing Fire Intensity And Changing Fire Source Locations

The fire source is a mixture of 120 ml gasoline and 30 ml diesel. At the first experiment, the fire source is set on the floor between the second room of sleeping carriage, and at the next one, on the floor between the fifth near the front door. Time is recorded at the fire start. The time-temperature curves are shown in Fig.9-Fig.10 (similar curves omitted) from which the following conclusion can be drawn.

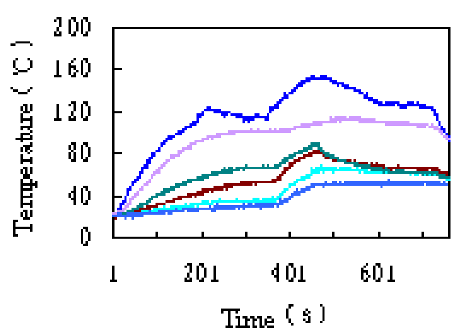

Figure 9. Temperature-time curve with a mixture of 120 ml diesel in both doors and the middle of window opened

When the fire source is in the middle of the carriage, the period reaching the highest temperature is longer than the corresponding period when the fire source is in the front. That is to say the partition walls between the rooms contribute to the prevention of the perfect combustion. The following can be observed in the experiments: when the fire source position is in the middle, the corridor and the rooms near the fire source is full of smoke, because cool air sweeps off hot smoke. The vague smoke layer can be observed near both of the doors. The smoke between the partition walls moves disorderly. More smoke moves backwards than forwards because of the inertia.

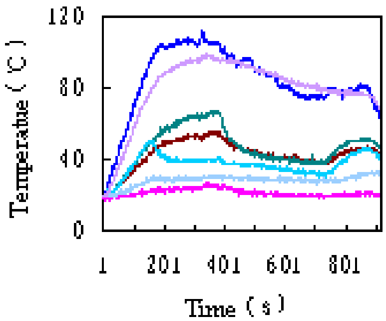

Figure 10. Temperature-time curve with a mixture of 120 ml gasoline and 30 ml diesel in both opened doors

4. Discussions

Generally speaking, there are six characteristics of the fire in the carriage of the running passenger train:

I. The fire intensity and the combustion velocity have main effect on the temperature in the carriage.

II. The different fire source locations have great effect on the temperature field and the flowing characteristics of the smoke. When the fire position is in the front, the smoke mainly flows backwards, but in the middle, a little counter-flows of smoke occurs.

III. The open-or-close state of both doors clearly effects the flowing of the smoke:

   i. With the both doors closed, the temperature rises quickly and the fire may be extinguished because of the lack of oxygen.

   ii. With the both doors opened, the temperature rises slowly, and the steady combustion keeps a longer time.

   iii. With the both doors first open, and then closed after a while, the temperature may be lowered.

IV. A discharge-smoke exit (100×100) designed by the authors is set at the top of the car (see Fig.1). When the discharge-smoke exit is opened, in all experiments, the temperature is lowered clearly, and thickness of the smoke-layer is reduces greatly.

V. The smoke can fill in the car in short time. The smoke mainly flows to both of the doors. More smoke flows to the back door than to the front door.

VI. When both of the doors are opened and the fire source position is in the middle of carriage, the visibility in the front of fire source is poorer than that in the back, where the smoke is turbulent between the partitions.

5. Conclusion

The small-scale experiment is an effective way to study the fire behavior. It can simulate the fire process to certain extent. Its results and the data are useful for the fire hazard analysis and full-scale experiment. But further research on the data and more effective use of results are needed in the future.

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