Effect of the Open Ways of Screen Doors on Fire Smoke in a Subway Platform

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Abstract

Under certain conditions, the screen doors of the platform can affect smoke spread and evacuation in a subway fire. The physical model and mathematical model were established by taking a real subway station as an example. And the smoke spread in a train fire was simulated by using CFD method. Effect of four open ways of screen doors on fire smoke and evacuation were analyzed. The research can provide a theoretical basis and technical support for the emergency evacuation plan and performance-based design of the subway.

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1. Introduction

Along with the rapid development of economy in China, the traffic in many large cities is getting more and more crowded in recent years. As an economic and environmental traffic method with a big load and fast speed, now subway becomes the main transportation tool for people who live in big cities. But certain hazards exist along with the conveniences subway brings to us. There is a huge people and property loss resulted from the subway fires happened in home and abroad in recent years. Fires maybe caused by the aging of the wire of electric devices and the short circuit and overload of the electric devices equipped in the train bodies.

The subway platform storey mainly consists of platform and tracks which seperated by screen doors. The screen floors will open for passengers to get on and off when a subway arrives at the platform. When a fire occurs in a subway, screen doors must be open for passengers to evacuate to the platform, so the smoke of fire will spread to the platform and will influence the evacuation of the people on platform. So it is necessary to study the influence of the screen doors to the fire smoke. Based on a real subway station, the influence of the open methods of screen doors to smokepread when a fire occurs is studied by designing related fire scenarios and using CFD method.

2. CFD Numerical Modeling

The NIST Fire Dynamics Simulator (FDS) [1] predicts smoke and/or air flow movement caused by fire, wind, ventilation systems, and other sources of momentum. A post-processor called Smokeview can be used to visualize the predictions generated by NIST FDS. FDS solves a form of the Navier-Stokes equations appropriate for low-speed, thermally-driven flows of smoke and hot gases generated in a fire. FDS was developed to specifically address fire-hazard scenarios. It is a finite-difference, large-eddy simulation (LES) model. Heat release from the fire is modeled via Lagrangian thermal elements (LTEs). The LTE is a Lagrangian particle that releases a specified amount of heat in a prescribed time and rate. In FDS, knowledge of a fire's heat release rate (HRR) history is required. The known HRR is distributed amongst a user specified number of LTEs which are introduced from the fire source at regular intervals. Each LTE induces buoyancy as it “burns out,” contributing to the flow throughout the computational domain. Smokeview visualizes FDS computed data by animating time dependent particle flow, 2D slice contours and surface boundary contours. Data at a particular time may also be visualized using 2D or 3D contour plots or vector plots.

3. Physical model and initial setup

3.1. Brief introduction of the real subway station

The real subway station this paper based is a underground two-island platform with two storeys. There are two island platforms of 230m×12.5m×1.25m size with a total length of 536m. The width of these platforms are set according to the factors of the possible amount of passengers in a long fututre of 2030, the length of train compisition and the stairways (escalators) between platforms and booth floors. The passengers through this station are mainly from an airport. There are subterranean passages between the airport and the station.

The booth floors in this station are set at basement first. The public zone of the booth floor is divided into a pay area and a non-pay area. After passing the pay area, the entering passengers will go downstairs to different platforms to wait for the subways. The outbound passengers (departures) will go upstairs to the booth floors and to the non-pay area, then go to the airport terminal through the subterranean passages.

3.2. Fire Scale and fire position

According to the “credible and the most unfavorable” principle, it is considered that a fire occurs in a single train when it stop by the platform. The automatic fire fighting system is out of work, the fire occurs in a middle car, and the schale of the fire is about 36MW, the fire growth rate is set as a rapid T-squared fire. The position of fire source is displayed in fig.1.
3.3. Mechanical smoke extraction

The storey of platform is divided into three track zones (see Fig.1). According to the “Shanghai civilian construction smoke extraction code” DGJ08-88-2006, the amount of smoke extracted from a single track zone is 341004 m$^3$/h, under the condition of 36 MW train fire and a $z=2.1$ m visible height. There are 25 extraction vents uniformly distributed in a single track zone, the area of a single extraction vent is 1×1 m$^2$ and the wind speed in outlet is 3.79 m/s.

The area of single public zone in both sides of track zone on fire is 2160 m$^2$, the amount of smoke extraction is 129600 m$^3$/h based on 1 m$^3$/ (m$^2$·min) construction area of one smoke zone. And the amount of additional added wind is 50% of the amount of smoke extraction (64800 m$^3$/h). When a train fire occur in track zone, the mechanical air supply in public zone is turned on to make sure that the platform is under a positive pressure to stop or delay the spread of smoke to the public zone in platform.

3.4. Fire scenario design

In order to analyse the influence of the different open methods of screen doors in platform storey to fire smoke during train fires, four fire scenarios are designed under the following four conditions: the screen doors in both sides of the train on fire are closed, one side screen doors are open, both side screen doors are open and there is no screen doors. Table 1 and Fig.2 display the detail information of fire scenarios.

<table>
<thead>
<tr>
<th>Fire scenario</th>
<th>Fire Scale</th>
<th>Smoke extraction method</th>
<th>Method to add wind</th>
<th>The status of the screen doors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire scenario 1</td>
<td>36.0MW</td>
<td>Extraction in track zone (341004 m$^3$/h)</td>
<td>add wind naturally</td>
<td>Both sides screen doors open</td>
</tr>
<tr>
<td>Fire scenario 2</td>
<td>36.0MW</td>
<td>Extraction in track zone (341004 m$^3$/h)</td>
<td>mechanical air supply in the public zone in screen doors open side (64800 m$^3$/h)</td>
<td>the screen doors in the side of the train on fire are open and the other side are closed</td>
</tr>
<tr>
<td>Fire scenario</td>
<td>36.0MW</td>
<td>Extraction in track zone (341004 m$^3$/h)</td>
<td>mechanical air supply in the public zone in both sides of track</td>
<td>Both sides screen doors are open</td>
</tr>
<tr>
<td>Fire scenario</td>
<td>36.0MW</td>
<td>Extraction in track zone (341004m³/h)</td>
<td>mechanical air supply in the public zone in both sides of track zone (64800m³/h)</td>
<td>No screen doors</td>
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</tr>
<tr>
<td>Fire scenario 4</td>
<td>36.0MW</td>
<td>Extraction in track zone (341004m³/h)</td>
<td>mechanical air supply in the public zone in both sides of track zone (64800m³/h)</td>
<td>No screen doors</td>
</tr>
</tbody>
</table>

4. The simulation results and analysis

4.1. The influence of different open/close methods of screen doors to smoke spread

Fig.3 displays the three mension pictures of the smoke in track zone in platform storey. When the train fire is occur, the amount of smoke is big because of the large fire load, and the smoke is rising rapidly along with the rise of heat smoke plume, and when it arrive at the ceiling fo the track zone, it spread to both side and the bottom immediately. It is showed that the smoke don’t spread to the bottom because of the mechanical extraction under the four open/close methods of screen doors. At the same time along with the area between track zone and platform is getting small and small, the degree of smoke spread is getting bigger and bigger. Such as the smoke almost spread to
the bottom of the track zone after 1200 during the fire scenario of both sides screen doors open, but the smoke under the fire scenario with no screen doors almost even don’t spread to the middle of the track zone after 1200s.

Fire scenario 1: The screen doors in both sides of the train on fire are closed

Fire scenario 2: The screen doors in one side of the train on fire are open

Fire scenario 3: The screen doors in both sides of the train on fire are open

Fire scenario 4: There is no screen doors in the train on fire

Fig. 3 the three dimension figure of the smoke in track zone in platform after 1200s
4.2. The influence of different open/close methods of screen doors to visibility

Fig.4 displays the sectional view of the visibility distribution in the place of 2.1m away from the ground of platform. It can be seen that the visibility in most places is bigger than 10m after 1200s for all the four scenarios, except fewer places in track zone where the visibility is lower than 10m. So the influence of smoke invisibility to evacuation is small. The detail situations are as following: the visibility under the condition of no screen doors is the biggest one, and for the scenarios with both sides screen doors open and only one side screen doors open the visibility is smaller, and the visibility for the scenario of both sides screen doors close is the smallest.

Fig.4 the sectional view of the visibility distribution in the place of 2.1m away from the ground of platform after 1200s

4.3. The influence of different open/close methods of screen doors to temperature

Fig.5 displays the sectional view of the temperature distribution in the place of 2.1m away from the ground of platform. It can be seen that the temperature in the place of 2.1m (except the place right above the fire source) is lower than 60°C after 1200s. So the influence of smoke temperature to evacuation is small. The detail situations are as following: the temperature is getting higher and higher along with the smaller and smaller of the open area between track zone and platform. And the temperature under the condition of both sides screen doors close is the highest one and the one with no screen doors is the lowerest one.

Fig.5 the sectional view of the temperature distribution in platform track zone. It can be seen that after 1200s the highest temperature spots of screen doors near fire source under any scenarios are located in the top of the track zone and all their temperatures are about 450°C. The temperatures in higher places of screen doors are the
highest one of up to 200°C under the scenario of both sides screen doors close. In order to guarantee the security of people evacuation, the screen doors should have the ability to bear 200°C temperature.

Fire scenario 1: The screen doors in both sides of the train on fire are closed

Fire scenario 2: The screen doors in one side of the train on fire are open

Fire scenario 3: The screen doors in both sides of the train on fire are open

Fire scenario 4: There is no screen doors in the train on fire

Fig. 5 the sectional view of the temperature distribution in the place of 2.1m away from the ground of platform after 1200s
5. Conclusion

Upon above the following conclusions are obtained:

- (1) For the 36MW train fire, the amount of smoke extracted mechanically can meet the requirement of people evacuation in all four scenarios in the real subway station mentioned above. The close of screen doors can prevent the smoke in track zone from spreading to the platform and prolong the time for evacuation. So it is suggested that the screen doors should be closed as soon as possible after the people evacuated from the train.

- (2) For the 36MW train fire, the degree of smoke spread in track zone, the temperature and visibility in the place of 2.1m away from the ground of platform, and the temperature of fire source are getting bigger and bigger, along with the smaller and smaller of the open area between track zone and platform for all four scenarios.

- (3) Through simulation, the temperatures in the top of the track zone are about 450°C. The temperatures in higher places of screen doors are the highest ones of up to 200°C under the scenario of both sides screen doors close. So it is suggested that the screen doors should have the ability to bear 200°C temperature or be protected by many sprinklers distributed close.

Reference