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Short communication

Combustion performance of flame-ignited high-speed train seats via full-scale tests☆

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ABSTRACT

Determining the combustion characteristics of combustibles in high-speed trains is the foundation of evaluating the fire hazard on high-speed trains scientifically, and establishing effective active and passive fire precautions. In this study, the double seats in the compartments of CRH1 high-speed trains were used as the main research object. Under different test conditions, including the power of ignition sources and ventilation rates, full-scale furniture calorimeter tests were conducted to study important fire combustion characteristics such as the ignition characteristics of seats, heat release rate, mass loss rate, total heat release, temperature variation, and smoke release rate. The relationships among these parameters were analyzed and summarized into combustion behavior and characteristics, thus providing fundamental data and reference for the development of fire precautions and safety design of high-speed trains. The results in this test are as follows: (i) The double seats of high-speed trains are relatively easy to ignite and susceptible to the fire ground environment. (ii) The combustion temperature in the test apparatus exceeded 600 °C in only 2 min for the larger ignition source. (iii) The heat release rate exceeded 800 kW. (iv) The total heat release resulted mainly from flame combustion. (v) The final mass loss rate was ~30%. (vi) The lowest light transmittance was <25%. (vii) The change process of temperature with time has the same trend as the change process of heat release rate. (viii) Suppressing flame combustion and controlling the smoke generated from the seat materials themselves played key roles in retarding the combustion of high-speed train seats.

1. Introduction

With the rapid development of social economy, science, and technology, the high-speed railway in China has undergone rapid development. Currently, the extent of high-speed railway operation in China ranks first in the world. According to the *Mid- and Long-term Development Plan of Integrated Transport Network in China* reference required, the operating mileage of the railway network in China will exceed 120,000 km by 2020, and that of the constructed passenger lines will exceed 16,000 km. However, fire safety of high-speed trains has not been investigated in detail in China [1,2].

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A high-speed train has typically a narrow and confined space, where combustibles are relatively concentrated and there are a relatively small number effective fire safety and precaution systems are available. Thus, the fire has the potential to spread quickly and rescue becomes difficult in case of a fire. Thus, train fires can seriously threaten human life and traffic safety and easily lead to a crash tragedy and cause adverse social impacts. The fire precautions for high-speed trains have attracted attention in many countries. As representatives of developed countries, Japan, Germany, and the United States have set up professional fire research institutions that have conducted several fruitful studies [17–19,22]. Their research has mainly focused on selecting flame-retardant train body materials, establishing standards for fire precautions, and optimizing the structure of train. The results obtained in these studies have witnessed a certain success in their practical applications in high-speed trains [3–6].

Compared to other countries, domestic studies on high-speed train fire precautions are still scarce in China. The only reported studies are confined to qualitative descriptions and summarization of the reasons, fire characteristics, and fire and emergency management of high speed train fire safety, in addition to a small number of studies on FDS numerical simulation. These studies are nor directly relevant and unable to reflect the actual fire scenarios [7–9]. A complete system of high-speed train fire precautions has not been established yet in China, nor systematic studies on the characteristics of train combustion, smoke spread, personnel evacuation, fire precautions, and design for retarding fire growth. In particular, only a few studies have been conducted on the combustible characteristics of high-speed train compartments and materials, and full-scale tests have been rarely conducted.

The compartments of high-speed trains mainly consist of the train body, seats, baggage, curtains, and other materials. The train body is mostly noncombustible or difficult to burn; therefore, the combustion of high-speed trains is primarily the complex heat and mass transfer processes of combustibles that are composed of seats, passenger baggage, curtains, and other components under various environmental coupling effects. Once the potential for fire ignition and spread is known for high-speed trains, several types of effective and feasible, active and passive fire precautions can then be established. The first step is to determine the combustion behavior and characteristics of various combustibles, among which passenger seats play a relatively significant role in high-speed train compartments [1,2].

In this study, the double seats in the compartments of CRH1 high-speed trains were used as the main research object. Under different test conditions, including the power of ignition sources and ventilation rates, full-scale furniture calorimeter tests were conducted to study the important fire combustion characteristics such as the ignition characteristics of seats, heat release rate, mass loss rate, total heat release (THR), temperature variation, smoke release rate (SRR). The relationships among these parameters were analyzed quantitatively and summarized into combustion behavior and characteristics, thus providing fundamental data and reference for the development of appropriate fire precautions and safety design of high-speed trains.

2. Compartment model and materials

The CRH1 high-speed train has been widely used on Chengdu–Guan County high-speed railway, Suining–Chongqing railway, Beijing–Shanghai high-speed railway, Shanghai–Hangzhou high-speed railway, and Guangzhou–Shenzhen railway, usually with a speed up to 200 km/h. The compartments of CRH1 high-speed trains are divided into first-class, second-class, and dining compartments. Their setting situation and detailed parameters are shown in Table 1. The detailed profile and plan are shown Figs. 1–3 [1,2].

A first-class compartment of CRH1 high-speed train contains 77 seats that are distributed in the form of 2 + 2 with a seat width of 500 mm; a second-class compartment contains 101 seats that are distributed in the form of 2 + 3 with a seat width of 450 mm. The outer layer of seats is mainly composed of synthetic fiber, while the internal filling material is polyurethane foam [1,2].

3. Test equipment and method

The fire combustion characteristics in these tests were measured mainly based on the principle of oxygen consumption. The equipment and site of tests are shown in Figs. 4 and 5. The full-scale combustion structure was constructed in accordance with the GB/T27904-2011 standard [10], and the fume-collecting hood used had a cross section of 3 m × 3 m and a height of

Table 1
Setting situation and detailed parameters of first-class, second-class, and dining car compartments.

Number	Item	Type of compartment		
		First-class compartment	Second-class compartment	Dining compartment
1	Number of compartments	2	5	1
2	Seat distribution	2 + 2	2 + 3	2 + 3
3	Number of seats in every compartment	72	101	19((fixed seats)) + 24((dining car seats))
4	Width of seats	500 mm	450 mm	–
5	Front-back distance	970 mm	900 m	–
6	Width of passage	600 mm	580 m	–