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An experimental investigation on thermal characteristics of sidewall fires in corridor-like structures with varying width

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A B S T R A C T

In order to study the effect of aspect ratios on thermal characteristics of sidewall fires in corridor-like structures, a set of small-scale experiments on sidewall fires was conducted in a model channel with adjustable width. The effects of channel widths on fire burning rates and the temperatures below the ceiling are analyzed. In the experimental-set width range, the changes for the fire burning rate, ceiling jet flame length and ceiling temperatures above the fire source are insignificant. However, when the width decreased to a certain value, the width has a significant effect on the ceiling temperatures in the downstream of fire source, especially near the opening end. The ceiling temperatures increases with the decreasing of channel width. Compared with the longitudinal direction, at the position with a certain distance transversely away from the fire source, the temperatures below the ceiling are more significantly affected by the channel width.

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1. Introduction

In recent years, fires in long channels have attracted extensive research attention (e.g., [1,2]) due to its catastrophic consequence. The long and narrow channels usually have various aspect ratio of height to width due to different application purposes. When a fire occurs in a long channel, such as tunnels or corridors, different aspect ratios may have different effects on the fire development.

Previous studies have been done on the effect of the aspect ratio on fires properties in long channels [3–9]. Kurioka et al. [3] experimentally investigated the fire properties at the near field of fire sources in tunnels with rectangular and horseshoe cross-sections. Empirical models were developed for flame tilt, flame height, maximum temperature of the smoke layer and its position. The aspect ratio of tunnel cross-section was incorporated in these models. Carvel et al. [7] compared the heat release rates of fires in tunnels to the heat release rates generated by fires in the open space based on experiment data in the literature. They found that the heat release rates in tunnels were influenced primarily by the tunnel width and ventilation, and a fire would tend to have a higher heat release rate in a narrow tunnel. Li and Ingason [8] proposed the correlations of the maximum ceiling excess gas temperature under low and high ventilation flows in tunnel fires. Data from numerous model scale tests and most of the large scale tunnel fire tests were used and analyzed. The results indicated that the maximum ceiling temperature was independent of the tunnel width, which was in line with the finding by Lönnermark and Ingason [9] who used a wide range of tunnel widths in a model scale test series and were not able to find any effect of the tunnel width on the maximum ceiling temperature. However, in previous studies, they did not consider the fire source adjacent to the sidewall in which condition more heat would radiate back to the fuel surface.

Some prior researches have suggested that the sidewalls affect the fire burning rate and flame development [10–14]. Casale and Marlair [10] noted that the burning rate of a pool fire in a tunnel was higher than that in the open space due to the significant re-radiation from heated walls. The fire near a sidewall in a corridor-like structure represents a relatively dangerous fire scenario by observation. It easily causes structural damage with flame directly heating the near sidewall and ceiling. Ji et al. [15–17] experimentally investigated the influence of different transverse fire locations on maximum smoke temperatures under the tunnel ceiling. They found that the maximum ceiling smoke temperature rises keep almost unchanged as the fire moves closer to the sidewall at the beginning and then increase significantly after the distance between the fire and the sidewall decreases to a certain value. And the correlation of the temperature distribution under the ceiling was developed by taking the fire location into account. Imazeki et al. [18] found that the hot current developed toward the tunnel center downwind from the fire source near a wall through experiments in a tunnel with longitudinal ventilation. They investigated

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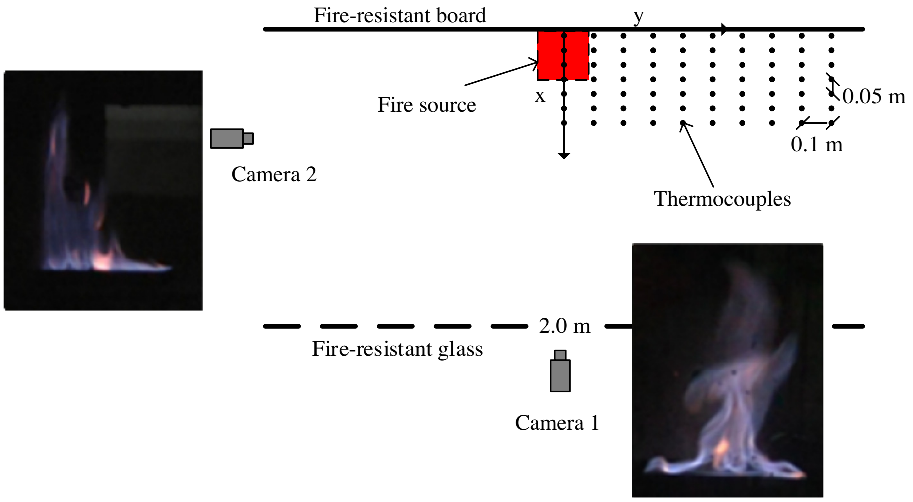
the cause by numerical simulation which showed that the spiral air by the fire plume created a vortex in the crevice between the wall and the plume. However, in above studies, the width of corridor-like structures is fixed, and the effect of the cross-sections on the distribution of ceiling temperature needs to be studied further.

For a sidewall fire in a channel, the fire burning characteristics are mainly influenced by the nearby sidewall and ceiling, such as limited air entrainment and enhanced radiation heat feedback. The effect of the other sidewall may be insignificant. However, in the channels with different width, the influence of the sidewall which the fire is not adjacent is also different. In current study, a set of experiments were conducted to study the effect of channel width on the burning rate and ceiling temperature distribution for sidewall fires.

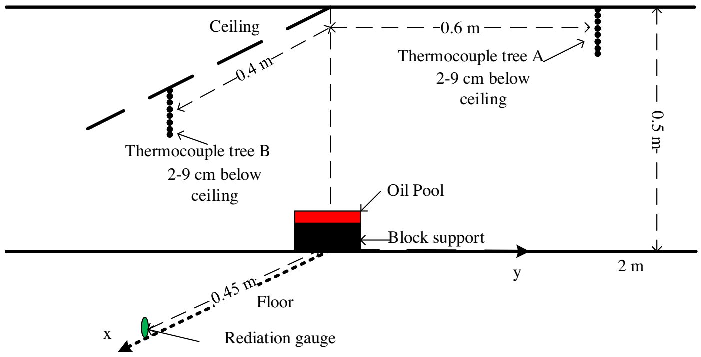
2. Experimental setup

Fig. 1 shows the small-scale model channel apparatus. The channel model is 2 m in length, 0.5 m in height, and with adjustable width between 0.5 and 1.5 m. The ceiling, floor and the sidewall attached by pool fires were made of 4 mm thick steel plate, with a 30 mm thick fire-resistant board as inner lining. The other sidewall is movable, made of 8 mm thick fire-resistant glass for observation purposes. Methanol pool fires were used as fire sources, and placed against the sidewall at the longitudinal center of the channel. The experimental conditions are shown in Table 1. The effective ceiling height, H_{ef}, which was specified as the distance between the pool bottom and the ceiling, was adjustable. All pools were made of 2 mm thick steel plates and have a depth of 20 mm. The initial fuel thickness was kept at 1 cm before ignition. The ambient temperature was recorded by a mercury thermometer before each experiment, which was ranging in 293–295 K. The typical cases were repeated for three times and the results presented good repeatability with discrepancies less than 5%.

The fuel mass versus time was recorded by an electronic balance of CPA34001S from Sartorius (maximum 34 kg, precision 0.1 g). Panasonic cameras (HDC-TM700) with spatial resolution of 1920×1080 and frame rates of 25 fps were used to record the experimental process from two sides of the model as shown in Fig. 1(a). The ceiling temperatures were measured by K-type (chromel–alumel) fine wire thermocouples with diameters of 1 mm and response time less than 1 s. The uncertainty of these thermocouples was estimated to be less than 5%. The detailed thermocouples positions arrangement below the ceiling is shown in Fig. 1(a). Seventy thermocouples were positioned 1 cm beneath the ceiling with the transverse distances from the sidewall of 0.01, 0.05, 0.1, 0.15, 0.2, 0.25 and 0.3 m, respectively, and with an interval of 0.1 m along the longitudinal direction. Two thermocouple trees with eight probes were positioned below the ceiling from 2 to 9 cm with an interval of 1 cm, as shown in Fig. 1(b). Thermocouple tree A was 0.6 m longitudinally away from the pool center and thermocouple tree B was 0.4 m transversely away from the sidewall. A water-cooled radiation gauge was positioned 0.45 m transversely away from the sidewall with 2.5 cm above the floor.



a. The thermocouples positions with 1 cm below the ceiling by top view.



b. The thermocouple trees and rediation gauge positions.

Fig. 1. Schematic of experimental apparatus.

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