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Experimental Study on Vertical Fire Spread of Thin Hanging Combustibles

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Abstract

In order to study vertical fire spread law of thin combustibles hang in atrium, the vertical combustion characteristics of thin combustibles was tested using vertical combustion experimental equipment, limited oxygen index tester and calorific value analyzer. Combustion parameters such as oxygen index, calorific value, vertical fire spread rate, surface temperature, mass loss rate and heat release rate were obtained. Fitting line showed that vertical fire spread rate, mass loss rate and heat release rate can be expressed as a power function of burning time. Vertical fire spread was accelerated growth, which the fire spread rate is over ten times of horizontal fire spread rate. The maximum surface temperature of the combustion cotton was about 500 °C, the maximum surface temperature of the combustion cardboard was about 700 °C. Experimental results showed that the thin combustibles hang in atrium and other large spaces have a greater fire risk, its vertical fire spread is very fast, so fire prevention measures should be taken in practical applications.

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Keywords: atrium; hanging combustible; vertical combustion; fire risk

Nomenclature

OI	Oxygen Index (%)
ΔH	calorific value (kJ/kg)
H	flame front position (mm)
v	fire spread rate (mm/s)
$\dot{Q}$	heat release rate (kW)
m	mass (kg)
$\dot{m}$	mass loss rate (kW)
t	time (s)
Greek symbols	
χ	non-dimensional combustion efficiency
Subscripts	
1	first time test
2	second time test
3	third time test

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1. Introduction

Modern large public buildings generally have tall atrium through several floors. The atriums improved ventilation and lighting conditions inside the building, but they also bring a lot of new fire safety issues [1]. In performance-based fire protection design, atriums and pedestrian streets were often regarded as "quasi-security zone". If fire occurred in atriums and pedestrian streets, great threat of buildings will be brought. Business atriums often decorated with various thin hanging combustibles and this increase the danger of vertical fire spread. Therefore, the study on vertical fire spread law of thin combustibles hang in atrium is very important for fire protection design of buildings.

The arrangement of combustibles has an important influence on their combustion characteristics. The combustion characteristics of vertically arranged materials are significantly different from horizontally arranged materials. In the process of vertical hanging materials combustion, oxygen supplied from both sides and flame spread from the bottom up. This type of downstream fire spread has extremely fast spread rate and large flame will appear soon. Guo-qing ZHU et al [2-4] done series of studies on vertical combustion characteristics of the canvas. Their studies showed that the fire spread rate of burning canvas is very fast and oil paints on canvas will accelerate the speed of the fire spread. The flame was columnar and showed as an angle of 10 °-15 ° v-shaped flame. Panorama museum canvas fire model was extremely fast t^2 fire. Long CHEN et al [5] concluded that vertical fire spread of curtains was an accelerated process. The average rate of the first half of burning process was 1.15 cm/s, the average rate of the second half of burning process was 4.74 cm/s, the average rate of the whole process was 1.77 cm/s. Li-zhen WANG et al [6,7] wrote programs to solve the fire spread characteristics and discussed fire spread behavior, flame shape and flame spread rate of cotton. Drysdale and Macmillan [8] studied on the fire spread behavior of 1mm paper and PMMA in different widths. Rangwala and Jose [9] done theoretical predictions and experimental analysis of the lateral flame diffusion of materials which thickness less than 20cm. Quintiere, Hsin-Yi Shih et al [10,11] also studied on upward flame spread of thin materials. Many other researchers studied on the vertical fire spread and their emphasis was on thermal thick materials or one-sided flame spread [12-14].

In this paper, the samples used in the experiments were selected based on the size and texture of combustibles hang in atriums. They are cotton and cardboard. The vertical combustion characteristics of thin combustibles was tested using vertical combustion experimental equipment, limited oxygen index tester and calorific value analyzer.

2. Experimental design

2.1. Oxygen Index

Oxygen Index (OI) refers to the prescribed condition, the material has a minimum oxygen concentration required for flame combustion in the mixed gas stream of oxygen and nitrogen. It is represented with the volume percent of oxygen. High oxygen index indicates that the material is hard to burn, low oxygen index indicates that the material is easy to burn. Based on the oxygen index test standard GB / T2406-2008, the OI of materials were tested by limited oxygen index tester. The sample size was 140 mm × 52 mm. Each material was measured three times and took the average. Experimental apparatus and sample are shown in Fig. 1 and Fig. 2.

Fig. 1. Limited oxygen index tester

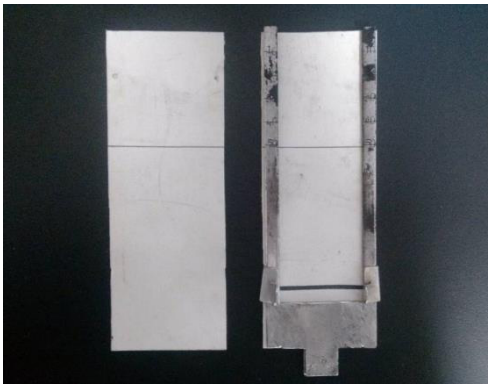

Fig. 2. Sample