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ScienceDirect

Procedia Engineering 135 (2016) 299 – 308

Procedia Engineering

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Oscillating behavior of fire-induced exchange flow through a horizontal ceiling vent

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Abstract

Oscillating behaviors of fire-induced exchange flow through a horizontal ceiling vent in a compartment were studied in this paper. Experiments were conducted in a ceiling vent compartment with inner dimensions of 180.0 cm(L) × 120.0 cm(W) × 120.0 cm(H). A single vent configuration in the middle of the compartment ceiling was used. Various patterns of flow were shown by using the principle of smoke particles of laser scattering. The ratio of cross section of outflow and ceiling vent area and the oscillation frequency of outflow will then be obtained by image processing technology. Useful experimental results on these flow characteristics are derived which can be used for mass flow rate model establishment.

Peer-review under responsibility of the organizing committee of ICPFFPE 2015

Keywords: Compartment fire, horizontal ceiling vent, instability of vent flow, oscillation frequency.

Nomenclature

f	oscillation frequency (Hz)
A	area (cm^2)
D	diameter (cm)
X	relative distance, horizontal distance between ceiling vent and fire source (cm)
Greek symbols	
Θ	area ratio between smoke through a sampling plane and sampling plane itself
Subscripts	
c	cold air through sampling plane
f	fire
s	hot smoke through sampling plane

1. Introduction

Ship fires are destructive and have drawn much attention in recent years [1-4]. The vast majority of ship cabins are below decks in most ships. Some of them, such as engine rooms, are confined without vertical opening in order to prevent the water from the sea. The deck hatches are located in the ceiling of the cabins which lead to the upper deck in these cabins. Researchers

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Peer-review under responsibility of the organizing committee of ICPFFPE 2015
doi:10.1016/j.proeng.2016.01.134

have started studying fires in confined compartments with single ceiling opening to simplify conventional ship cabins, for instance, to study flow through vents in the compartment, ceiling openings were simplified. To deepen understanding of the characteristics of exchange flow through horizontal vent, a Plexiglas with small openings in horizontal partition is used, such as in Epstein's fundamental study on buoyancy-induced flow [5], and in a well-known study by Tan et al. [6,7]. Until recently, studies have mainly focused on ceiling vent compartment fires, such as the research conducted by Tu [8], Wakatsuki [9], Chow [10, 11], Chen [12], Zhang [13], Li [14-16]. Such fires present an interesting challenge to fire modelers.

Calculating the mass flow through vents is the foundation of establishing the thermal equilibrium equation of the fire compartment. But the relevant researches on the flow through the horizontal ceiling vents of fire compartments are not sufficient, especially because of almost all of those models for calculating the mass flow through horizontal vents are based on the experiments of salt water simulation [5-7]. Previous fire studies found that the mass flow through the vent and the mass burning rate are dependent on the size of the vent in relation to the size of the compartment [13, 17].

The characteristics of flow through a horizontal vent include the ratio of cross section of outflow and ceiling vent area, oscillation frequency of outflow [18] and outflow pattern [5, 12]. The scope of present study focus on the ratio of cross section of outflow and ceiling vent area and the oscillation frequency of outflow. Only a single vent configuration in the middle of the compartment ceiling was used in the experiments. During the experiments, various forms of flow were shown by using the principle of smoke particles of laser scattering, the influences of the relative positions of fire sources and ceiling vents were investigated.

2. Experimental setup

Experiments were conducted in a ceiling vent compartment with inner dimensions of 180.0 cm(L) ×120.0 cm(W)× 120.0 cm(H), which was 1:2 reduced scale model for ISO 9705 room. The Compartment was built with 10mm thick rock wool sandwich construction. A heptane (C_7H_{16}) circular pool fire was positioned on the bottom of the compartment. The diameters of the pool fire used in the experiments were 10 cm, 14 cm, 20 cm and 30 cm. Only a single vent configuration in the middle of the compartment ceiling was used in the experiments. The dimensions of the ceiling vent used in the experiments were 20 cm×20 cm (400 cm^2), 30 cm×30 cm (900 cm^2), 40 cm×40 cm (1600 cm^2) and 60 cm × 60 cm (3600 cm^2). The initial fuel thickness was 35 mm for each test. Fig. 1(a) illustrates the schematic of the experiments.

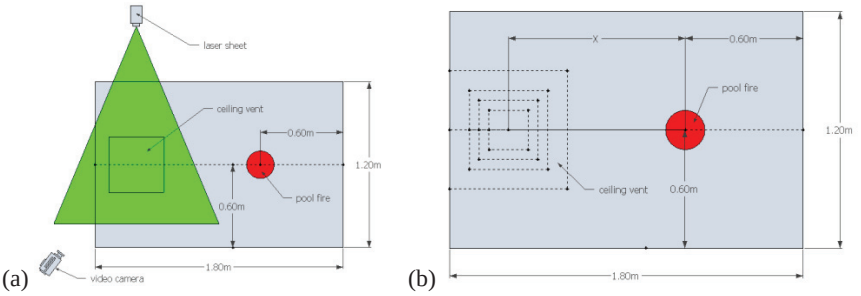

Fig. 1. Schematic of experiments (view from the top) for (a) the position of laser light sheet and (b) the relative positions of fire sources and ceiling vents

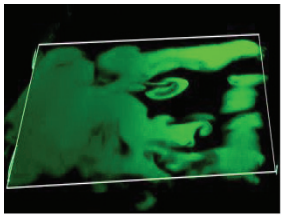

Fig. 2. Flows were shown by using the principle of smoke particles of laser scattering.

The influences of the relative positions of fire sources and ceiling vents were investigated. As shown in Fig. 1(b), the horizontal distances between ceiling vent and fire source, *X*, were varied by 30 cm, 50 cm, 70 cm, 90 cm. The scenarios of ceiling vent just above the pool fires, likewise, were studied in this paper. During the experiments, various patterns of flow