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Air pumping action of a plume in a room fire

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Research Article

Abstract

Air pumping effect of a fire plume to give higher intake rate through vertical openings in a post-flashover room fire will be discussed in this paper. The thermal balance equation was set up with known fire phenomena in a room. The hydrostatic model was applied to study the air intake rate through vertical openings. An equation relating heat release rate to room air temperature rise with empirical constants was then justified by reported experimental data on post-flashover room fire. The heat release rate was measured by the oxygen consumption method in that experiment. The predicted heat release rate from the empirical equation reported in the literature was observed to be proportional to the room air temperature rise as derived from hydrostatics. However, the proportionality constant is lower than the experimental value. A possible explanation is due to neglecting another fire phenomenon on air pumping action of the fire plume in a real room fire. Higher pressure differences across the door would give higher airflow rates across an opening. This would supply more air to give higher heat release rate as observed in the experiment. In this paper, the pressure due to air pumping of the fire plume is taken as a proportion of the hydrostatic pressure due to temperature differences between the upper hot layer and lower cool layer. Comparing the measured heat release rate with the estimated heat release rate due only to hydrostatics will give the air pumping action. The possible increase in heat release rate in a post-flashover fire can then be estimated accordingly.

Keywords

air pumping,
analytical model,
full-scale burning test,
hydrostatic model

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1 Introduction

Airflow rate through an opening in a room fire is important in determining the potential fire hazards as pointed out years ago (Kawagoe 1958). The minimum heat release rate to onset flashover (Babrauskas 1980; Babrauskas and Williamson 1978) in a room fire and the steady heat release rate for a ventilation-controlled fire can be estimated, as explained in many books (Drysdale 1999; Harmathy 1993). Numerous efforts have been made on deriving correlation equations on the airflow rates across an opening (Babrauskas 1980; Babrauskas and Williamson 1978; Chow and Zou 2005; Chow et al. 2003; Delichatsios et al. 2004; Drysdale 1999; Harmathy 1972a,b, 1979, 1980, 1993; Karlsson and Quintiere 2000; Kawagoe 1958; Nakaya et al. 1986; Prahl and Emmons 1975; Quintiere and Den Braven 1978; Rockett 1976; Steckler et al. 1982, 1984; Tanaka et al. 1985; Thomas 1976, 1981). A thermal balance equation was set up with known fire phenomena in the room fire. The pressure hydrostatic model (Kawagoe 1958) was applied to estimate the airflow rate across the opening. The temperature difference between the indoor hot gas and outside cool air layers would give the driving force for drawing outside air in and ejecting hot gas out. Full-scale burning tests were performed to derive the empirical parameters concerned. A linear correlation expression was determined on relating the airflow rate across an opening with the ventilation factor (Babrauskas 1980; Harmathy 1979, 1980, 1993; Prahl and Emmons 1975; Quintiere and Den Braven 1978; Rockett 1976; Steckler et al. 1982, 1984; Thomas 1981). Computational fluid dynamics (CFD) (Chow and Chow 2009) was also applied to simulate aerodynamics through a doorway induced (Chow and Zou 2005) by a room fire. Factors which are difficult to control in experiments but affecting the resultant airflow can be adjusted relatively easier in CFD simulations. Predicted airflow pattern and temperature contours were used to deduce the airflow rates.

In addition to the driving force from pressure difference

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