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Experimental study and numerical simulation for a storehouse fire accident

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ABSTRACT

Full-scale experiment and numerical simulations are carried out on a shelf fire in a storehouse to study the ignition manner, the fire spread and the combustion characteristics. A computational fluid dynamics (CFD) model of fire-driven fluid flow, FDS (Fire Dynamics Simulator), is used to solve numerically a form of the Navier–Stokes equations for fire. Ignition manner experiments with both cigarette ends and lighter are conducted first. Then a full-scale experiment on a shelf fire is performed. The temperatures are measured and the fire growth and spread process is analyzed. A numerical model is used to simulate the experiment; the temperatures, fire growth and heat release rate are studied. In numerical simulations, the grid size resolution is analyzed. The experimental results of temperatures and the fire growth and spread process are compared with the results of numerical simulations. It shows that the numerical results are in good agreement with the experimental results. The chimney effect is also observed in both the experiment and the simulation. These useful data can be helpful in the numerical reconstruction of the whole storehouse fire accident.

1. Introduction

Fire investigation is a scientific, practical and interdisciplinary work. Due to the complexity and uncertainty of combustion, fire investigation becomes the most important and difficult task for fire department. The investigation result of the fire not only offers the references to make and adjust the fire safety policies, but also gives the important professional opinions to the judicial authorities to use to identify the civil and criminal responsibility. This brings forward a very high requirement for fire investigation. Today, fire investigation mainly depends on the empirical or quasi-empirical method that the fire investigators accumulate, so the efficiency and technical tools in fire investigation are required to improve. However, reconstructions can be of particular value to a fire investigation.

Scientists will be interested in using the incident to improve fire statistics and fire science for a whole range of disciplines. The incident represents an uninstrumented experiment from which lessons can be learned about chemistry, engineering, management, human behaviour and psychology, within the context of fire. There are a large number of issues that can be addressed, examined or resolved by carrying out a fire reconstruction, including the fire origin and location, fire spread and growth, smoke propagation, material properties and structural response.

To reconstruct a fire scene, the best way is to do a full-scale experiment. However, full-scale fire experiment is expensive and time consuming. The repeatability is quite poor due to the unstable nature of fire. With the development of computer and CFD tools, computer simulation becomes an important tool to reconstruct a fire accident in fire investigation.

Numerical reconstructions require the model to simulate an actual fire based on information that is collected after the event, such as eyewitness accounts, unburned materials, burn signatures, etc. The purpose of the simulation is to connect a sequence of discrete observations with a continuous description of the fire dynamics. There is much more emphasis on such phenomena as heat transfer to surfaces, pyrolysis, flame spread, and suppression. A numerical reconstruction is a reverse problem because the outcome is known whereas the initial and boundary conditions are not. Therefore, optimization methods will be used to get the plausible fire scenario that is consistent with the collected evidence. The simulation is then used to demonstrate to fire service personnel why the fire behaved as it did based on the current understanding of fire physics incorporated in the model.

In general, a numerical reconstruction has the following steps.

(1) Carry out a part-scale experiment.
(2) Perform numerical simulations on the part-scale experiment.
(3) Make comparisons and calibrations between the numerical and experimental results to get an optimized numerical model.

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