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Fire scene reconstruction of a furnished compartment room in a house fire

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ABSTRACT

Computational fluid dynamics (CFD) has been employed to reconstruct the burning of solid combustible materials of a house fire in Parkes, New South Wales, Australia. Experiment was conducted in a compartment room containing multiple combustible materials with an identified ignition source. Large scale fire development involving the spread of flame and smoke leading to the untenable condition of flashover was observed from on-site visualisations as well as comparison to calculated heat release rates. Significant transient fire events taken from experimental footages including the spread of flame on furniture such as couch and carpet were captured through the numerical model. The present simulation and experimental studies are currently being utilised as components for online fire training program for fire-fighters.

Introduction

In September 2012, a series of fire test burns were carried out by Fire and Rescue New South Wales in a discarded furnished and carpeted house located in Parkes, New South Wales, Australia. The maximum heat release rate of the solid combustible materials in the house was estimated to be about 10 MW. CFD-based Large Eddy Simulation (LES) was carried out and visualised utilising the field model Fire Dynamics Simulator (FDS) and Smokeview (SMV) version 5.5.3. Simulation results were validated by comparing against thermocouple measurements while the spread of fire and smoke was compared against experimental video footages. The objective of this study is to provide simulated fire scene reconstructions for the online training program (i.e. E-Fire Investigation: http://www.efireinvestigation.com.au/), where fire-fighters can be trained through a proper understanding of the fire development in a compartment with specified amount of fuel loads.

With the rapid advancement of computational technology during the previous decade, fire modelling is gaining significant traction in fire investigation especially for the reconstruction of compartment fires [1–3]. The complex, interactive flame spreading behaviour can be modelled through the coupled sub-grid scale (SGS) turbulence, combustion and radiation submodels [4]. Nonetheless, the accuracy of numerical simulations of fire in a house depends greatly on the coupling of the solid pyrolysis model with gas phase combustion model since furniture items being present in the house represent the dominant fuel loads for large scale development of fire. The solid pyrolysis model adopted in FDS adopts a simple Arrhenius expression

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to describe the chemical reaction from the thermal degradation of solid to volatiles. Therefore, the generation of volatiles is determined via suitable input material properties.

Material properties

The material properties applied in this simulation study are summarised in Table 1. Input data values of fabric and polyurethane foam adopted in this study were validated by Jukka et al. [6] through cone calorimeter experiment of an upholstered coach chair. Other data including pine wood and gypsum plaster were validated from various studies [5,7,8].

Experimental setup

Experiments were conducted in a fully furnished room located at Parkes, New South Wales. The dimensions of the room and the configuration of furniture items are depicted in Fig. 1. The figure legend depicts the furniture and components in the compartment room. As can be seen, there are two couches, three wardrobes, one single bed and one drawer. Couches and bed were made of polyurethane foam with fabric coverings whereas wardrobe, drawer and cabinet were made of wood. Ignition of fire was realised via a wastepaper bin, sprayed with accelerant which was placed next to an armchair of the small couch. Bare-bead type K thermocouples with metal-sheathed fibre-glass extension wires were placed at different heights of 1.2, 1.7 and 2.3 m – one in the (nominal) bottom left corner of the room. Video footages of the fire were taken from a number of different locations within the room.

Numerical simulation

The boundary was extended at the openings exposed to the surroundings to improve the modelling of inlet and outlet flow structures. During the experiment, fire was started by throwing a lighted up match into a bin filled with papers with

Table 1
Material properties for the FDS model of the house fire.

Material	Fabric	Polyurethane foam	Pine wood	Gypsum plaster
Applied for	Bed coverings	Bed mattresses, coaches	Wardrobe, drawer	Compartment walls
Specific heat, kJ kg^{-1} K^{-1}	1	1	1.38	
Conductivity, W m^{-1} K^{-1}	0.1	0.05	0.14	0.48
Density, kg m^{-3}	100	40	489	1440
Heat of combustion, kJ kg^{-1}	15,000	33,280	14,500	
A	4.28E+14	1.69E+08	1.89E+10	
E	2.02E+05	1.35E+05	1.51E+05	
Heat of reaction, kJ kg^{-1}	3000	1750	430	

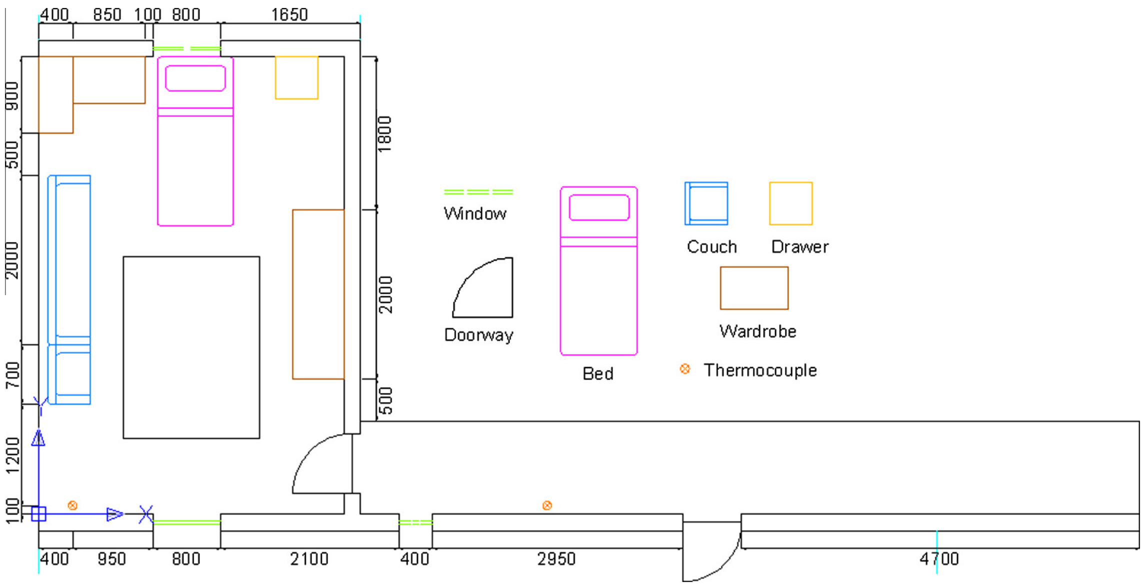

Fig. 1. Parkes test room floor plan (dimension in millimeters).