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# Numerical investigation on window ejected facade flames

M. Duny [a,b,*], D. Dhima [a], J.P. Garo [b], H.Y. Wang [b]

[a] *CSTB Centre Scientifique et Technique du Bâtiment, France*
[b] *ENSMA Ecole Nationale Supérieure de Mécanique et d'Aérotechnique, France*

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ABSTRACT

A numerical simulation was performed to assess the ability of the used code to model a compartment fire with external flames. Thereafter, numerical investigations were performed in order to study the influence of geometrical parameters such as opening dimensions, opening position and presence of sidewalls at the opening on window ejected flames. The influence of the heat release rate was also discussed. These studies highlight the different phenomena in each configuration and their influence on the risk of vertical fire spread. Moreover, to study the influence of sidewalls at the opening, numerical results were compared to Lu's correlation (Lu et al., 2013, 2014) [1,2]).

## 1. Introduction

The façade is the interface between the inside and outside of a building. In this area, a lot of factors that facilitate dynamics of fire converge (unlimited amount of oxygen, verticality of the surface, wind,…). When the wall cladding is combustible these factors can be damaging but the vertical spread of fire can occur even when the façade is not combustible. Recently, there has been growing interest in Fire Safety of Façade. Many researchers have extensively studied this topic experimentally [1–3] and numerically [6–7]. Factors affecting a fire are primarily the fire source (type, load and distribution) and ventilation, such as size of openings and rate of burning. Generally, external flames appear when air supply inside the compartment is no longer sufficient. This is controlled by the openings dimensions and these flames can be considered in terms of flame shape (Height, width and depth) [1–3]. This paper presents a numerical investigation on ejected flame behavior from enclosure fires in different opening configurations (opening dimensions, opening positions and distance between sidewalls at the opening) and for different heat release rates. The influence of these parameters on fire spread along a façade was widely studied using small-scale tests. For example, Lu [1–2] carried out a series of experiments on reduce-scale models and proposed to correlate opening dimensions and sidewalls distance (D) by a global dimensionless parameter in order to explain the sidewall effects. Tang [3] used a similar configuration in order to study the influence of dimensions of an opening on the external flame properties. However, all these experiments were performed using a low heat release rate (lower than 250 kW) and with compartments not exceeding 80 cm square in shape. The aim of the present study is:

1. To assess the ability of the used code (FDS) to model a compartment fire with external flames.
2. To numerically assess the influence of the opening dimensions and its position on the excess heat release rate due to the burning excess fuel outside the compartment.
3. To numerically assess the influence of a “U” channel configuration on flame height along the facade above the opening.
4. To verify if the correlations obtained by [1–3] for small scale tests (~50 kW) are available for large scale compartment fires simulated with HRR=5.5 MW and 6.5 MW.

Finally, this study will identify and quantify the influence of geometrical parameters on external flames.

## 2. Numerical simulations

The use of computational fluid dynamic (CFD) and zone model has become an alternative means to predict the effects of a fire both inside and outside the fire room. Their predictions need to be validated with results taken during full-scale experiments. That's why, this first part of this study consists in a simulation of a compartment-tested fire [5] and then in the comparison of measured and predicted temperatures along the façade in order to

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[*] Corresponding author at: CSTB Centre Scientifique et Technique du Bâtiment, France.
*E-mail address:* mathieu.duny@cstb.fr (M. Duny).

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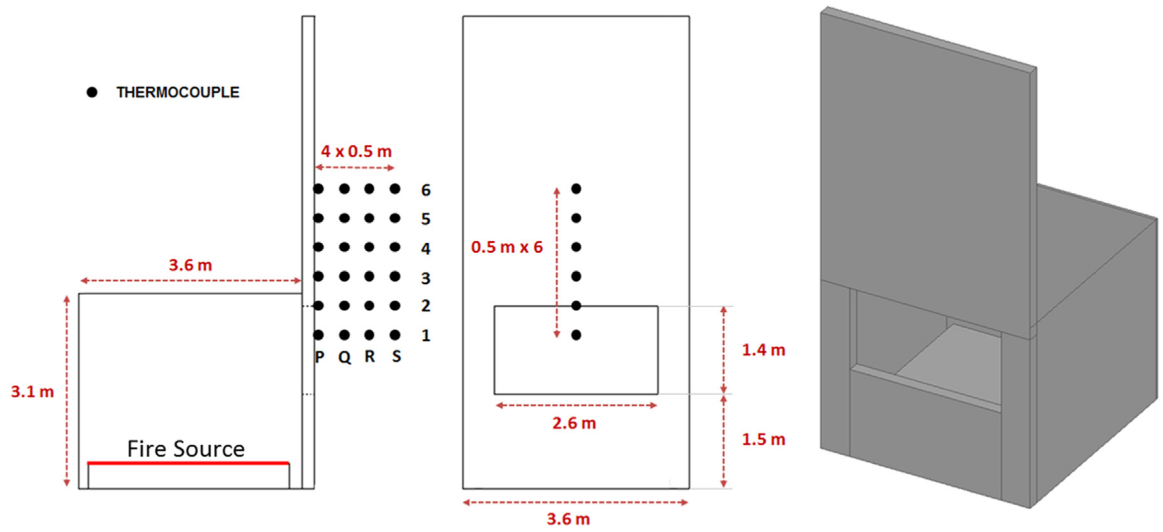

**Fig. 1.** Experimental and numerical setup for the simulation of a compartment fire.

**Table 1**
Material property for the façade wall.

| | Thermal conductivity (W/m K) | Density (kg/m$^3$) | Thermal specific capacity (J/kg K) | Thickness (m) |
|---|---|---|---|---|
| Façade – Ceiling | 0.20 | 450 | 1000 | 0.20 |
| Walls | 0.70 | 1600 | 840 | 0.12 |
| | 0.45 | 1050 | 840 | 0.20 |

assess the ability of the used code to model a compartment fire with external flames.

All the simulations were realized with the CFD (Computational Fluid Dynamics) tool FDS6.1 [4]. FDS default models were used to simulate each scenario. For any additional information about numerical models, the reader may refer to the User Guide [4]. The mesh cells used are cubic and measure 10 cm square. This value has been retained after a sensitive analysis using 5 cm, 10 cm and 20 cm mesh cells. Indeed, results with 20 cm were very away from experimental data and computation time with 5 cm was too long with no significant improvement in results. We assume that the flame area corresponds to an average gas temperature above 500 °C [5]. Below this value, there is no significant risk for exposed steel structures [8]. Flame height is calculated from the ground. Moreover, the excess heat release rate is calculated by the code.

### 2.1. *Simulation of compartment fire with external flames (validation case)*

The fire compartment configuration is shown in Fig. 1. Opening dimensions are fixed and there is no sidewall at the opening. Façade wall height is 6.4 m. The wall properties (density, thermal conductivity and specific heat) in cold conditions are known and the same values are taken into account for the fire simulations. These values are presented in Table 1. A series of temperatures have been measured along the facade with thermocouples. The experimental data are from [5]. Positions of thermocouples are shown in Fig. 1. The fuel used was wood cribs. The mass loss of wood cribs was measured (Fig. 2a) during the experiment and used as input data in the simulation. The mass loss rate is prescribed on the upper face of the block shown on Fig. 1. The heat release rate has been calculated with a heat of combustion of 17.5 MJ/kg. This value is calculated by the code using the amount of energy released per unit mass of oxygen consumed and fuel

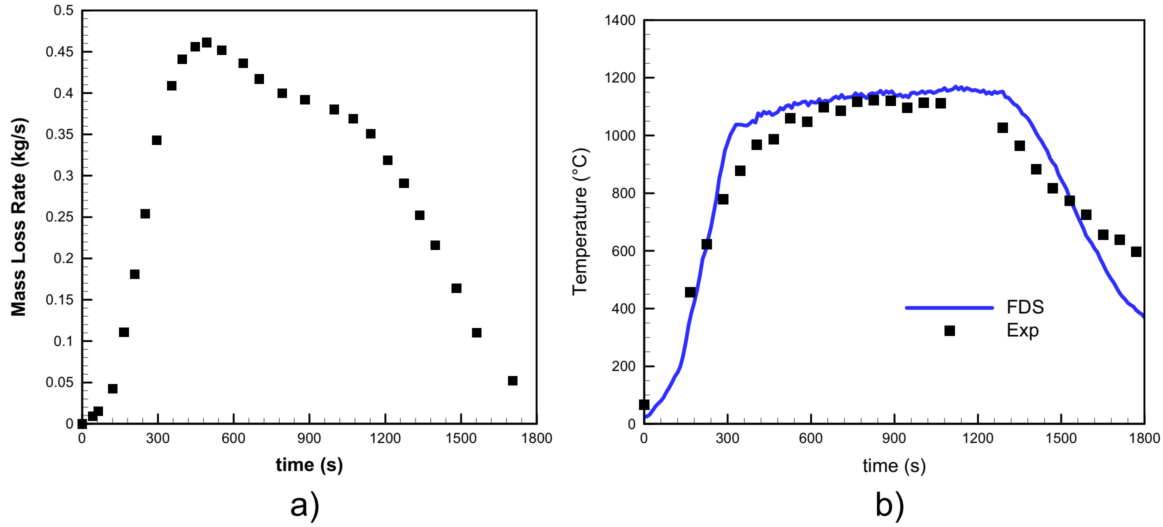

**Fig. 2.** a) Experimental mass loss rate used in the simulation. b) Evolution of temperatures inside the compartment.