Practical problems of model validation, selecting input data and material properties for engineering applications of CFD fire modelling

Piotr Smardz
INBEPO Sp. z o.o., Poland

Introduction

- CFD models are becoming a common tool in commercial fire engineering analysis
- Two aspects of CFD usage are of great importance to fire safety engineering practitioners:
  - validation of CFD models for the particular phenomenon / problem being investigated (as well as validation of the methodology of using the model to represent a particular fire problem)
  - selection of reliable material properties and physical parameters to describe the desired fire scenario

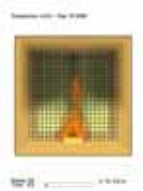
Scope of presentation

This presentation focuses on two selected aspects:

- validation of a selected CFD model for structural fire engineering applications (determination of thermal loading of structural elements exposed to fire)
- the issue of obtaining material properties and physical parameters for state-of-the-art fire modeling applications such as fire growth and fire suppression modelling

CFD models in FSE

- Relevant to several aspects of FSE:
  - **thermal loading of structural elements in fire conditions**
  - smoke movement analysis and assessment of evacuation conditions (ASET)
  - performance of fire suppression systems



- Both bespoke models for fire applications (**FDS**, Smartfire, Sofie) and general-purpose codes (Fluent, Phoenix)
- Referred to in EN 1991-1-2 as one category of the „advanced natural fire models”

Validation of CFD for smoke flow applications

Hot smoke tests (artificial smoke) are often carried out to verify performance of smoke control systems, e.g. during commissioning. Such test can be carried out in finished buildings, as they cause no damage.

Validation of CFD for smoke flow applications

Accidentally, they are also a good material for validation of CFD models for smoke movement and applications (HRR of the fire is known and smoke temperatures can be measured).

source: www.wikipedia.org

Topics requiring careful attention

Modelling a fire is a complex problem in its own, however the following tasks are particularly difficult:

- Modelling of under-ventilated fires (small as well as large compartments!)
- Modelling of fire growth in the initial stages
- Modelling of fire suppression (e.g. water mist)

Example – small compartment fire modelling

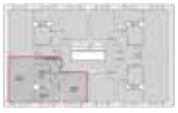
Comparison of CFD modelling with results of full scale fire test carried out in 2012 in a derelict apartment block in Bytom (Poland).

Research initiated and led by Częstochowa University of Technology, involved collaboration between academia, fire brigade and fire protection industry.

Two fire tests carried out: fully sealed compartment and a benchmark scenario with some ventilation.

Test arrangement and results relevant to modelling of under-ventilated fires.

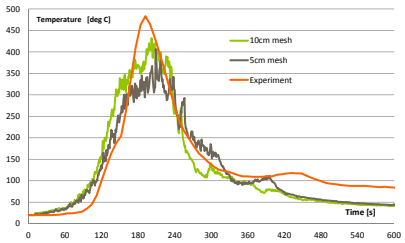
source: D. Saleta

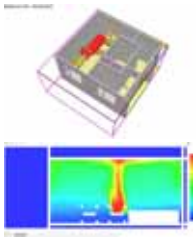


Example – small compartment fire modelling

Resonable qualitative agreement and hot-layer temperature prediction.

Highlighted difficulty of modeling the combustion processes occurring in severely underventilated fires when simple combustion model is used.

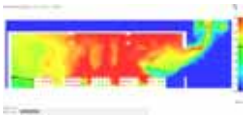




Example – medium-size compartment fires

Recent large-scale fire tests at Mokrsko (2008) and Ulster University (2010), although carried out with other objectives in mind are potentially a good source of experimental data for validation of CFD models with respect to under-ventilated fires. However, detailed information on the fire growth history is not available.

However there seems to be a problem with accurately representing the conditions inside the compartment when using the default combustion model in FDS.

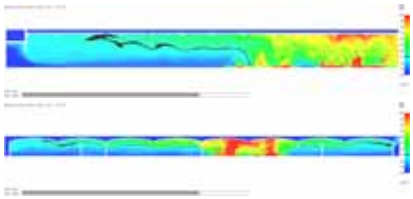


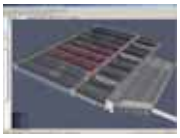
source: A. Nadjai et. al

Example – large compartment fire modelling

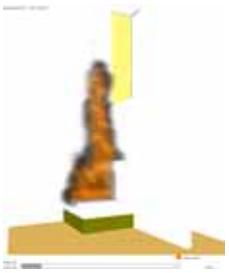
Attempt is being made to investigate the thermal conditions in the area of the fire origin using FDS. The main difficulty of the analysis is the size of the compartment, long fire duration and also ventilation conditions during the developed stage of the fire.

source: SITP





Example – fire growth modelling

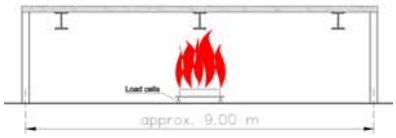


Qualitative comparison of FDS prediction of fire growth on a simplified seat arrangement with a small-scale field test. The main problem is the lack of material properties (ignition temperature, HRRPUA, heat of combustion) for the fuel material.

Scope of proposed research

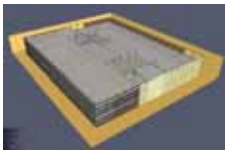
It is proposed to build a semi-full scale fire test stand to investigate heat transfer phenomena for a localized fire under a ceiling slab.

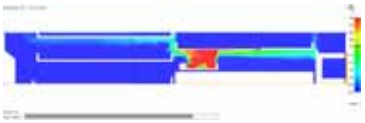
- Test stand consisting of concrete slab supported on steel beams and columns (similar to a portion of an open car-park geometry)
- Overall dimensions approx. 9 x 6 x 2.5 m high
- Test fires: heptane pool fires and wood crib fires (max. 2MW)

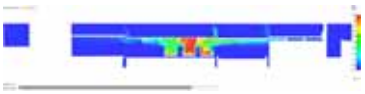


Relevance to real building construction?

The proposed test set-up is directly relevant to open-sided car parks, but also (after scaling) to larger halls and industrial buildings.







Aim of proposed research

- Provide results for comparison with CFD modelling (and also with simplified calculations based on the Eurocodes)
- Record and document in detail all fire test parameters and boundary conditions that may influence the results

Practical problems to be resolved

- Funding!
- HRR measurement to be achieved through mass loss rate measurements. (3-4 loadcells + data logger)
- Steel / concrete temperature measurements
- Radiative heat flux measurements

Thank you

piotr@inbepo.pl