CFD modeling of UMD-SBI fire for the MaCFP-3 Workshop

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CFD modeling of UMD-SBI fire for MaCFP-3 Workshop

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Introduction

The purpose of this modelling exercise is to contribute to the structured effort of the MaCFP workshop in the fire research community to make progress in fire modelling, specifically Single Burning Item (SBI) Test [1] in this case, using Computational Fluid Dynamics (CFD) code Fire Dynamics Simulator (FDS) version 6.7.9.

Experimental set-up

The experimental setup, shown in Fig. 1, was based on the Single Burning Item (SBI) test [1], but with symmetric panels. The burner was built exactly in accordance with EN 13823 [1].

The flame was allowed to spread until the HRR reached 300 kW. Once the HRR exceeded this threshold value, the propane burner was turned off and the flame was extinguished. Two 50 cm wide and 0.58 cm thick black PMMA panels having a total height of 146 cm were mounted onto Marinite I calcium silicate board (1.27 cm thick). Measurements including Heat Release Rate, heat flux to the wall, have been reported in [2].

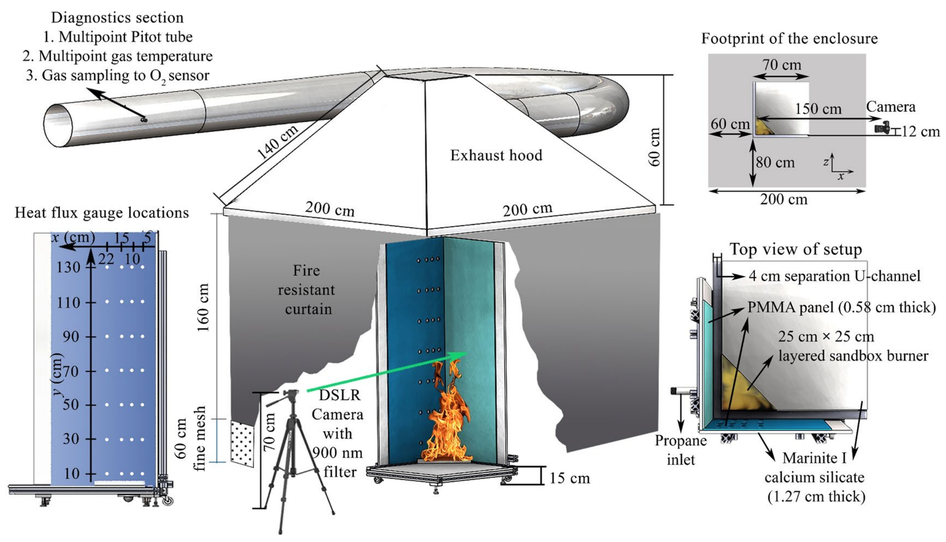

Fig.1 Schematic of the experimental setup [2].

Computational setup and material properties

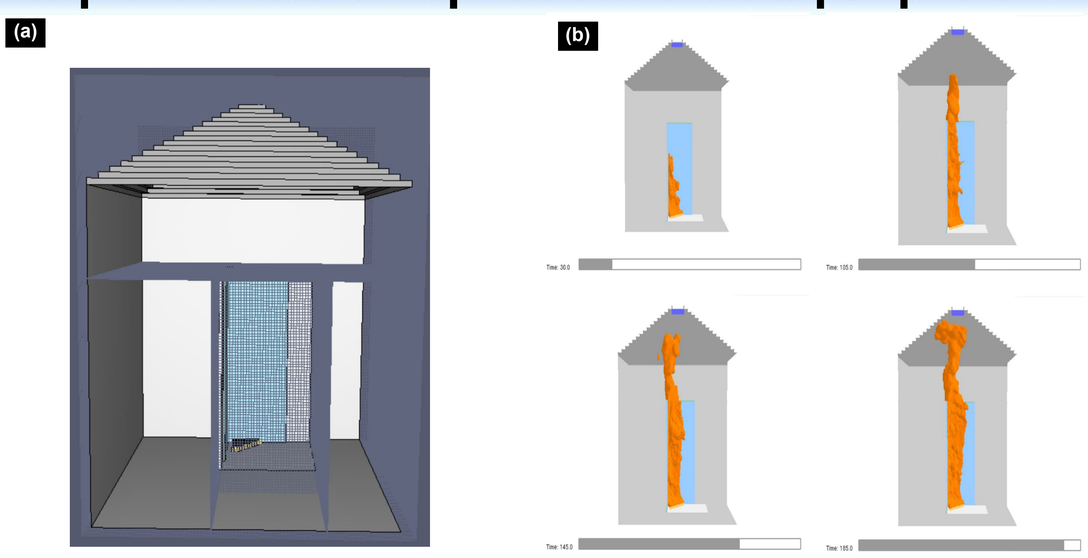

Fig.2 (a): Numerical domain setup image, (b) 200 kW/m^3 iso-contour of the volumetric heat release rate.

Domain size is 2.12 m by 2.12 m by 2.86 m (includes hood). Two sets of material properties for PMMA are investigated, namely the recommended UMD property set [3] and DBI property set [4]. Cell size is 2.5 cm and 1 cm for UMD properties [3], 2.5 cm for DBI properties [4]. Uniform grid size for the 2.5 cm cases while a local grid refinement for the 1 cm case (i.e., 1 cm grid size in the key areas and 2 cm elsewhere) as shown in Fig.2 (a). 300 angles have been considered in the radiation solver, 0.35 as radiative fraction. 1-step mixing-controlled reactions of MMA (burner) and MMA (pyrolyzate) in the combustion model.

More details about the numerical simulation and the FDS input files can be found in [5].

[1] European Committee for Standardization (CEN). Reaction to Fire Tests for Building Products – Building Products Excluding Floorings Exposed to the Thermal Attack by a Single Burning Item. Standard EN-13823, 2004. 6, 15, 22.

[2] D.M. Chaudhari, G.J. Fiola, and S.I. Stoliarov. Experimental analysis and modeling of buoyancy-driven flame spread on cast poly (methyl methacrylate) in corner configuration. Polymer Degradation and Stability, 2021.

[3] https://github.com/MaCFP/matl-db/blob/master/PMMA/Material_Properties/2021/MaCFP_PMMA_UMD.json

[4] https://github.com/MaCFP/matl-db/blob/master/PMMA/Material_Properties/2023/MaCFP_PMMA_DBI_calibrated.json

[5] https://github.com/MaCFP/macfp-db/tree/master/Fire_Growth/UMD_SBI/Computational_Results/2023/DBI

[6] https://github.com/MaCFP/macfp-db/releases/tag/SCRIPT_FIGURES

Simulation Results

Representative plots showing the instantaneous flame shape which is identified as the 200 kW/m^3 iso-contour of the volumetric heat release rate is shown in Fig.2 (b).

The HRR results of three cases are compared with the experimental data, as shown in Fig.3. Both the case with the UMD property set and 1 cm cell size, and the case with the DBI property set and 2.5 cm cell size, can reasonably predict the HRR. However, the case with the UMD property set and 2.5 cm cell size falls well below the experimental curve, particularly after 80 seconds.

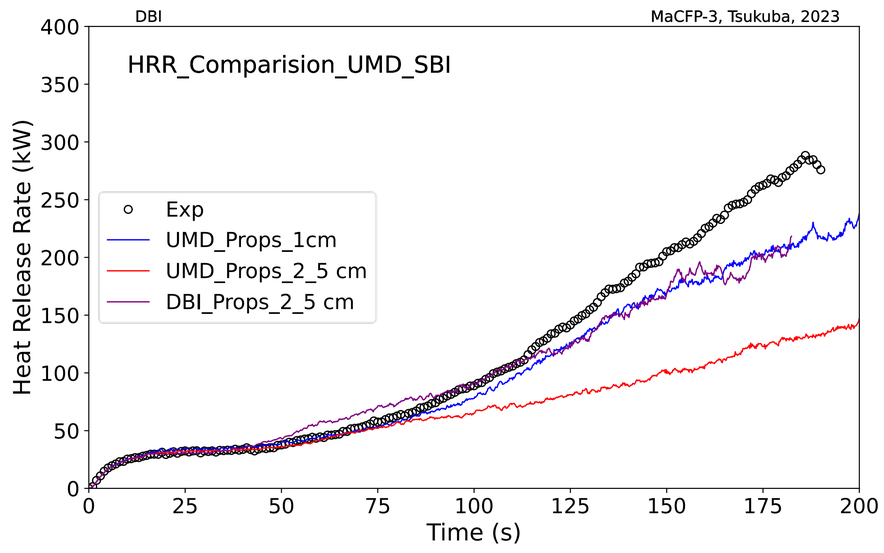

Fig.3 Heat release comparison between the simulation and the experimental data, three cases are investigated using two sets of material properties and two different cell sizes.

As shown in Fig 4, plots showing the time variations of the total gauge heat flux on the surface of one of the PMMA plate, for horizontal positions x=5 cm and 15 cm, and different elevations y values.

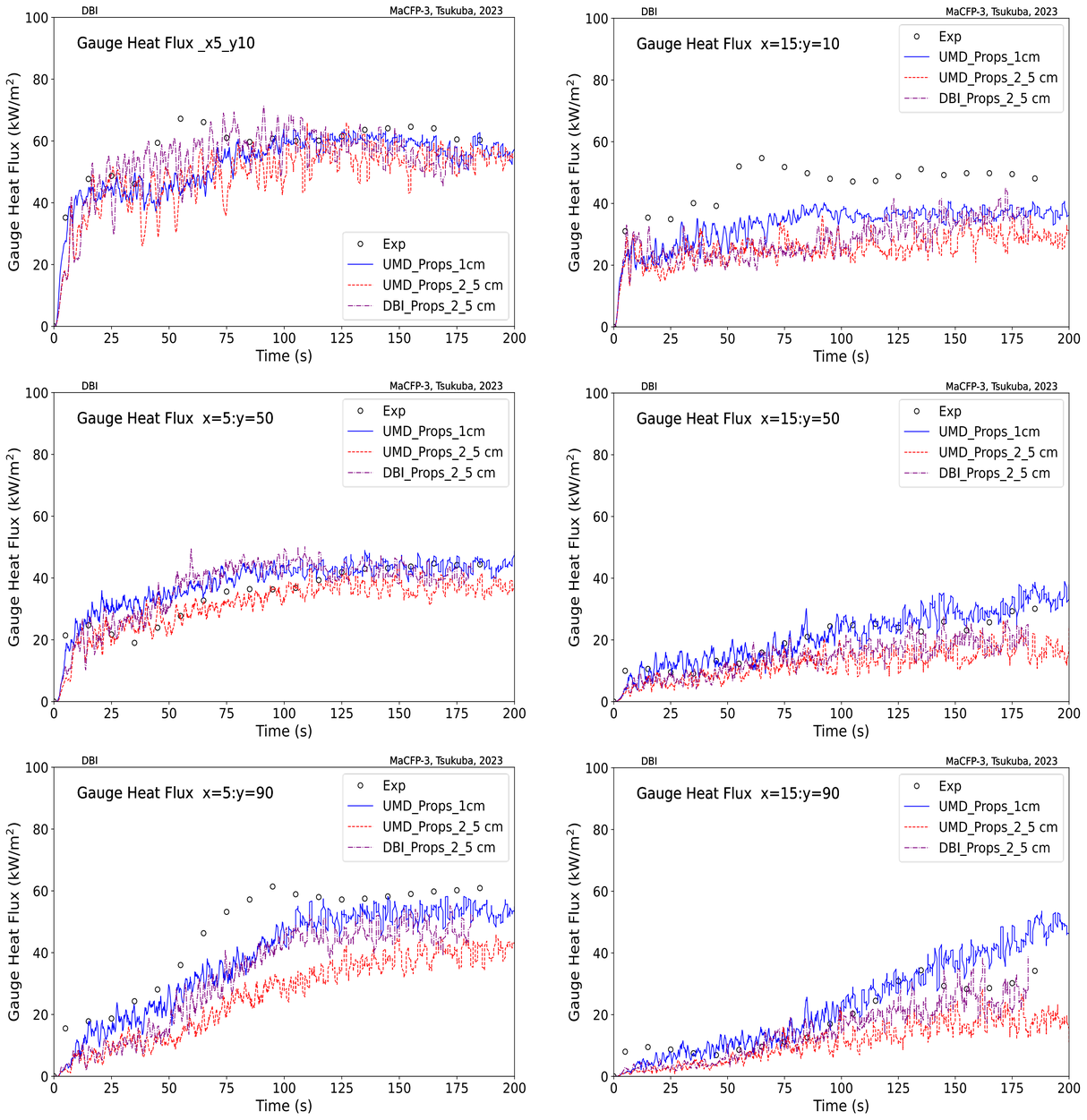

Fig.4 Time variations of the total gauge heat flux on the surface of the PMMA plate.

More information about the simulation results are available on the MaCFP github page [6].