A Multistep Computational Analysis of Pyrolysis and Flame Spread in Corner Configurations for MDF Panels

Davood Zeinali[1], Gaurav Agarwal[2], Ankur Gupta[2], Georgios Maragkos[1], Marcos Chaos[2], Tarek Beji[1], Joris Degroote[1], Bart Merci[1]

[1]Ghent University, Department of Flow, Heat and Combustion Mechanics, Belgium
[2]FM Global, Research Division, 1151 Boston-Providence Turnpike, Norwood, MA 02062, USA

EXTENDED ABSTRACT

Simulating the behavior of fires in corner configurations is a demanding fire modeling task that involves the prediction of pyrolysis and flame spread evolving both laterally and upward on flammable surfaces. The fire modeling code FireFOAM [1] has been used to evaluate the current capabilities in prediction of such fire development behavior. A multistep computational analysis has been made through simulations of three different sets of available experiments, comprising Single Burning Item (SBI) tests [**2**] conducted with Medium Density Fiberboard (MDF) and calcium silicate panels, as well as small-scale Fire Propagation Apparatus (FPA) tests [**3**] with MDF panels.

The computational analysis pivots on three distinctive verification steps. At first, the modeling of condensed-phase pyrolysis is verified through simulation of FPA pyrolysis experiments carried out with sample MDF boards in a pure nitrogen atmosphere. Next, the gas phase combustion modeling is verified through simulation of SBI corner fire tests carried out using nonflammable Calcium Silicate panels. Subsequently, as a final step, a verification is made of the joint interaction of these two fundamental modeling components, i.e. condensed-phase pyrolysis and gas phase combustion, through simulation of SBI tests carried out using the flammable MDF panels tested earlier in FPA. The purpose of this practice is to isolate the verification of each core modeling component, namely by modeling each element in absence of the other. Hence, provided that the first two verifications are promising, the ultimate premise is that the joint interaction of these components should yield reasonable flame spread and fire growth predictions in the final verification step.

The available FPA pyrolysis experiments consist of a number of tests carried out with sample MDF panels at FM Global in the US along with spectral measurements. A controlled nitrogen atmosphere was used and multiple radiative heat fluxes were considered, namely 25, 50, and 100 kW/m^2, with three repeatability experiments at each radiative heat flux. The material pyrolysis data consisted of the evolution of mass loss, surface temperature, and backside temperature of the samples. Based on the spectral measurements and according to the procedure described in [4], the effective absorptivity and emissivity of the sample MDF boards were determined. Other necessary material properties were estimated during the course of pyrolysis modeling in FireFOAM according to the procedures outlined in [4, 5]. In particular, the effects from the non-uniform nature of the density distribution through the thickness of the MDF panels were investigated, constituting a separate research study [6]. Correspondingly, an effective parabolic through-thickness density profile was estimated for the MDF panels. This estimated through-thickness density profile is also utilized in the present study.

The SBI tests with MDF panels [7] as well as inert Calcium Silicate panels have been conducted at the facilities of WFRGent NV in Belgium. The available dataset consists of through-thickness and backside panel temperatures, total heat fluxes at the standard thermal attack calibration points of SBI [**2**], mean flame heights, and the evolution of the total heat release rate (HRR) and smoke production rate (SPR). The flame spread is available via camera footage which has been analyzed using software as in [8, 9] to arrive at the mean flame heights of the corner fire.

Figure 1 shows a brief set of results from the conducted computational analysis, concerning the non-oxidative pyrolysis mass loss of MDF samples in FPA, the mean flame heights in the corner configuration of SBI with nonflammable calcium silicate panels, as well as the evolution of total Heat Release Rates (HRR) in SBI configuration with MDF panels. The pyrolysis modeling can be considered very reasonable if one takes into account the simplicity of the single-step-reaction representation in FireFOAM (i.e. virgin ⟶ char + pyrolysate). Similarly, the gas phase combustion modeling represents the SBI experiment with nonflammable calcium silicate panels very adequately. Considering that the burner in the SBI experiments has a triangular shape and its flames interact with a corner boundary configuration, the modeling results of mean flame heights are very satisfactory. The mean flame heights in FireFOAM have been determined through a 99% volumetric HRR criterion [10] and with respect to the concept of 50% intermittency [11] monitored at a time resolution of 0.01 s. The modeled total heat fluxes are in the order of the experimentally observed values as well. In the SBI corner configuration with MDF panels, the total HRR profiles in the simulations are generally in very good agreement with the experiments as Figure 1.c suggests. Nevertheless, the mean experimental peak HRR is underestimated

by approximately 12 kW. On the contrary, the lateral flame spread in the simulations is slightly faster than that observed in the experiments. The upward flame spread behavior has been captured well nevertheless. The mean flame heights determined via software analysis of the experimental footage indicate a rapid rise in the first minutes, followed by a gradual decline after 6 minutes into the experiment, both of which are captured well in the simulations. In this case, nonetheless, a 95% volumetric HRR criterion proves more adequate as small detached pockets of volumetric HRR are observed on the upper part of the computational domain. A brief sensitivity analysis of the volumetric HRR criterion has been made and the effect has been quantified in the SBI configuration with both flammable and nonflammable panels.

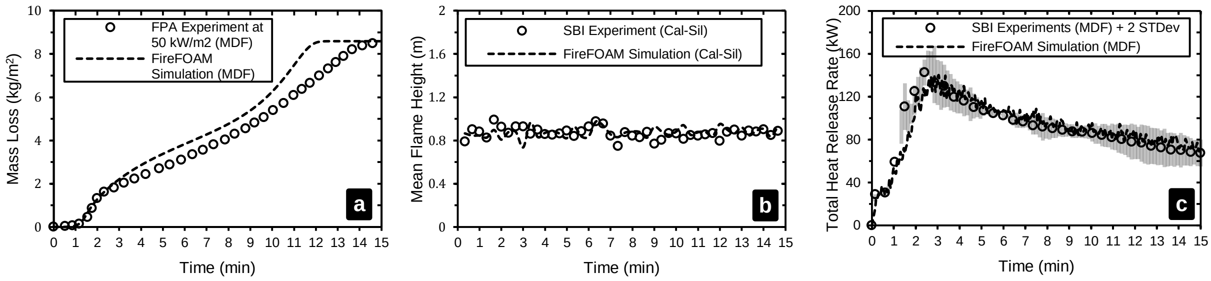

Fig. 1. Modeled (dashed lines) versus experimental (symbols) results of non-oxidative pyrolysis mass loss of MDF samples (diagram *a*), mean flame heights in the SBI corner configuration with calcium silicate panels (diagram *b*) and total heat release rates in the SBI corner configuration with MDF panels (diagram *c*). The shown experimental heat release rate evolution in diagram *c* is the average of three repeatability experiments with the shaded area denoting two standard deviations.

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