Large Eddy Simulation of Turbulent Vertical Wall Fires

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Large eddy simulations (LES) of turbulent wall fires are presented in the context of a vertically-oriented porous burner with a variety of fuels (methane, ethane, ethylene and propylene) and fuel flow rates. The modeling tool is a newly developed LES solver – FireFOAM. The modeling configuration is based on a previous experimental setup. Several modeling options for combustion and turbulence are investigated. It is found that the convective heat transfer is sensitive to the near-wall performance of the turbulence model. In this study, the wall-adapting local eddy viscosity (WALE) model is adopted to describe sub-grid scale turbulence, because of its advantage in representing near-wall scaling of the eddy viscosity. The combustion is modeled using a modified Eddy Dissipation Concept (EDC) model by introducing a diffusion mixing time scale for the near wall laminar region. In a preliminary step and in order to reduce the uncertainty associated with modeling of soot formation, the wall flame is treated as optically-thin (radiation absorption effects are neglected) and a fixed radiant fraction is assumed when modeling radiation emission.

The objectives of the present work are two-fold. The first objective is to perform a series of wall-resolved (fine-grained) simulations aimed at understanding computational grid requirements and at providing insights into the flame-to-wall heat transfer. The second objective is to investigate wall functions and to improve heat transfer calculations for coarse-grained engineering simulations. The wall-resolved simulations are evaluated against a previously established experimental database. The simulations are in good quantitative agreement with the experimental data. The fine-grained simulations show that 10 computational grid cells are needed across the wall-to-flame layer in order to provide grid converged solutions; this requirement corresponds to a grid resolution of a few millimeters in the present configuration. The accuracy of the heat transfer calculation decreases significantly when the grid size reaches a centimeter scale, especially in the region of fuel release (i.e., the pyrolysis zone), where there is a significant decrease in the convective heat flux due to fuel blowing. These results confirm that wall models are needed in coarse-grained engineering simulations in order to correctly predict the wall temperature and velocity gradients. In the present study, the performance of different wall functions is evaluated by comparisons with the wall-resolved simulations. A good agreement is obtained in both the pyrolysis and non-pyrolysis regions. These wall functions improve the ability of FireFOAM to model fire spread in large scale configurations.