PhD Research Project

Modeling of finite rate chemistry effects in the combustion of solid fuels relevant to fire safety problems

Points of contact :

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Location : the PhD position will take place both in France and the USA : 18 months at the University of Maryland, USA, and 18 months at Institut Pprime, FRANCE.

Background :

Fire safety engineering makes extensive use of CFD-based simulation software, for instance the Fire Dynamics Simulator (FDS) and FireFOAM. CFD-based fire models provide a description of the thermal decomposition of solid fuels, of the turbulent flow, mixing and combustion processes, and the resulting convective and radiative heat transfer that control flame spread and fire growth. In FDS and FireFOAM, the thermal decomposition of solid fuels is typically described using simplified single-step chemistry models and the combustion is described assuming fast equilibrium chemistry. The present project is aimed at bringing more detailed information on solid decomposition chemistry and gas-phase combustion chemistry into CFD-based fire models. Detailed information on chemistry is required for a description of ignition and extinction phenomena as well as a description of soot formation and the emission of toxic products.

The proposed work will take place in a succession of four major phases:

- Phase 1 will focus on the combustion chemistry of fuel-air mixtures characterized by different fuels and different fuel-air ratio conditions, ranging from well-ventilated to under-ventilated. The selected fuels will be representative of the pyrolyzate gas produced by thermally-degrading solid materials. The combustion conditions will vary from fast to slow chemistry. A finite rate, detailed chemical kinetic model taken from the literature will be selected and implemented into the CFD fire model FireFOAM. Phase 1 will take place at the University of Maryland during months 1-10 of the PhD project.
- The detailed chemical kinetic model selected in phase 1 will then be evaluated by comparison with experiments performed in a controlled atmosphere cone calorimeter. The cone calorimeter will be instrumented with a flame imaging system, thermocouples and gas analysis. The experiments will use wood. The experimental campaign will be aimed at characterizing the gas-phase combustion and emission processes as a function of radiant loading and oxidizer composition. Phase 2 will take place at Institut Pprime during months 11-22 of the PhD project.
- The comparison between experimental data and FireFOAM results obtained with a detailed chemical kinetic model performed in phase 2 will then provide the basis for developing a reduced (skeletal) kinetic model adapted to a CFD-based description of combustion of the pyrolyzate gas produced by thermally-degrading wood materials in configurations

representative of fire problems. Phase 3 will take place at Institut Pprime during months 23-28 of the PhD project.

- In a final phase, the reduced kinetic model will be implemented into FireFOAM and tested. The series of test will focus on the ignition and extinction limits of combustion fueled by thermally-degrading solid materials. Phase 4 will take place at the University of Maryland during months 29-36 of the PhD project.