Evaporation models of droplets subjected to high temperature gasses for LES of spray flames

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ABSTRACT

Lagrangian particle transport is widely used to represent fuel sprays in computational fluid dynamics simulations. In this context droplets may be characterised by their location, velocity, size, and temperature, if the Biot number of the droplet is low enough to assume constant liquid temperature (i.e.: fine sprays). The evolution of droplet size and temperature are strongly coupled, as the droplets are cooled by evaporation, and in return the rate of evaporation is profoundly sensitive to the droplet temperature. The evaporation process is characterised by the conservation of mass and energy, described by two ordinary differential equations heavily relying on semi-empirical models determining the rate of heat and mass transfer.

In this work, we explore the performance of different evaporation models in the context of spray combustion. In particular, the behaviour of the models is assessed under conditions, where the droplets are subjected to high temperature partially reacted gasses. In these circumstances Stefan flow (outward flow of the freshly evaporated fuel) plays an important role in the heat and mass transfer. The studied models are: Bird's correction[1], the Abramzon & Sirignano model[2], and the Langmuir-Knudsen model[3]. All models consider the effects of Stefan flow, in addition the Abramzon & Sirignano model considers the interaction between Stefan flow and forced convection, while the Langmuid-Knudsen model introduces non-equilibrium thermodynamics effects.

The different alternatives are assessed analytically in terms of equilibrium "wet-bulb" temperatures and evaporation rates. Moreover the models are validated against single droplet measurements. Finally, the performance of the models is assessed in the large-eddy simulation (LES) of gas turbine model flames of the Cambridge Spray Flame Database[4]. The study shows, that correctly considering Stefan flow is crucial in the simulation of systems where the droplets are subjected to partially reacted gasses.

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