A ROBUST STATISTICAL MODEL FOR THE EVAPORATION OF MULTICOMPONENT-FUEL DROPS CONTAINING A MULTITUDE OF CHEMICAL SPECIES

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The modeling of multi-component drop evaporation has been the subject of extensive research due to the fact that most fuels are complex mixture of pure species. Such studies have typically focused in the past on either the accurate description for a small number of components (e.g. Abramzon and Sirignano 1989, Lara-Urbaneja and Sirignano 1981) or on limiting situations such as the fast evaporation limit wherein all fuel components at the drop surface evaporate in proportion to their surface mass fraction (e.g. Law and Law 1982); for this latter situation, the drop size decreases, but its composition does not change. More recently, Tamim and Hallett 1995, and Hallett 2000 have proposed a model addressing the limit of very slow drop evaporation where the characteristic time of evaporation is less than or similar to that of diffusional processes in the drop. This model was built on continuous thermodynamic concepts (e.g. Gal-Or et al. 1975) that describe the fuel composition using distribution functions, and used specific distribution functions proposed by Whitson 1983. In this limit, the composition of the drop changes during evaporation. The mathematical form of the distribution function was initially assumed according to Whitson 1983, and it was postulated that the mathematical form is maintained during the drops lifetime, albeit with changing distribution mean and variance. This distribution is function of a unique variable, which is the fuel molar weight.

Applications of this model by Lippert 1999, and by Le Clercq and Bellan 2002, indicated that the model of Tamim and Hallett 1995, and Hallett 2000, while having good potential, is not robust. The model breaks down for relatively volatile fuels, such as gasoline or kerosene, or even when relatively less volatile fuel (such as diesel fuel) drops are exposed to an environment at moderate temperature (e.g. 500K) where the evaporation rate is similar to the internal diffusion rate. This lack of robustness was traced to the assumption of the unchanging mathematical form of the distribution function during evaporation.

To remedy this weakness of the original formulation of Tamim and Hallett 1995, a model is here proposed that is built on a realistic distribution function constructed by emulating the distribution found during the evaporation of a fuel containing a discrete mixture of twenty-four alkane hydrocarbons. During this stage of model development, the drop-size and temperature time evolution obtained from simulations using the original formulation are utilized as inputs, and the goal is the determination of a mathematical form of the distribution that closely resembles that found from the discrete model and that is simple enough to be used in simulations containing millions of drops. The mathematical form of this distribution function is further tested during calculations where the drop size and temperature evolve in time concomitant with the parameters defining the specific shape of the distribution function. This test encompasses a multitude of drop far-field conditions (both composition and temperature) as well as several fuels (i.e. diesel, gasoline and kerosene). Conclusions are presented regarding the contributed improvements of the new model and the usefulness of this new approach.

Acknowledgment

This research was performed at the Jet Propulsion Laboratory (JPL) of the California Institute of Technology, under the partial sponsorship of the U.S. Department of Energy (DOE), with Mr. Neil Rossmeissel (DOE Headquarters) and Mr. D. Hooker (DOE Golden Center) serving as contract monitors, under an agreement with the National Aeronautics and Space Administration. Additional sponsorship was provided by the Donors of The Petroleum Research Fund, administered by the American Chemical Society. Computational resources were provided by the supercomputing facility at JPL.

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