Numerical Simulation of Evaporating Sprays in a Convective Flow Field

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Abstract

In this paper, the direct quadrature method of moments (DQMOM) and the discrete droplet model (DDM) in an axisymmetric, two-dimensional configuration are used to model an evaporating water spray carried by nitrogen, the spray is injected into a vertical spray chamber. The models include the Abramzon and Sirignano model for convective droplet evaporation, and droplet motion is included by considering droplet drag and gravity. In DDM, the effects of the two-phase flow are captured by solving the gas phase conservation equations considering the droplets as point sources. DQMOM considers the inlet gas flow properties to compute the drag force exerted on droplet velocity. The phenomena of droplet – droplet interactions are currently neglected as the liquid volume in the present case is small. Appropriate initial and boundary conditions as well as the starting values for simulations are generated from experimental data, which have been carried out by the group of Prof. G. Brenn at TU Graz, Austria. The measurements were performed with phase Doppler anemometry (PDA). The experiment gives the spray characteristics (droplet size and velocity) at different cross sections away from nozzle exit. The DQMOM and DDM simulation results are compared with experimental data at these cross sections, and very good agreement with experiment is observed.

Figure 1 shows the computed and experimental profiles of the Sauter mean diameter at cross sections 0.12 m (left) and 0.16 m (right) away from nozzle exit. The DDM simulation result matches quite well the experiment at the center of the spray at 0.12 m from nozzle exit, but slightly under-predicts towards the periphery of the spray. Good agreement is observed at 0.16 m cross section between DDM and experiment. The DQMOM simulation results are in nice agreement with experiment at 0.12 m downstream the nozzle exit, and it is closer to the experimental data at higher radial distance. Further downstream, at 0.16 m from the nozzle exit, the DQMOM simulations reveal some scattering near the centerline, and at higher radial distances, they under-predict the experimental results. This discrepancy may result from the numerical scheme which employs an explicit finite difference method to solve the DQMOM transport equations; the results may be improved by implementing an implicit method.

The overall shape of a hollow cone spray is captured quite nicely by both methods, although some deviations are observed, particularly in DQMOM as compared to experimental profile, that might have resulted from the present DQMOM formulation, which is not yet fully coupled with the gas phase equations. Moreover, the discrepancies in the DQMOM results may stem from post-processing of the experimental data which is done to correct the number frequency at every measuring position to rule out the fluctuations in the effective cross section area of the measuring volume for the larger droplet sizes.

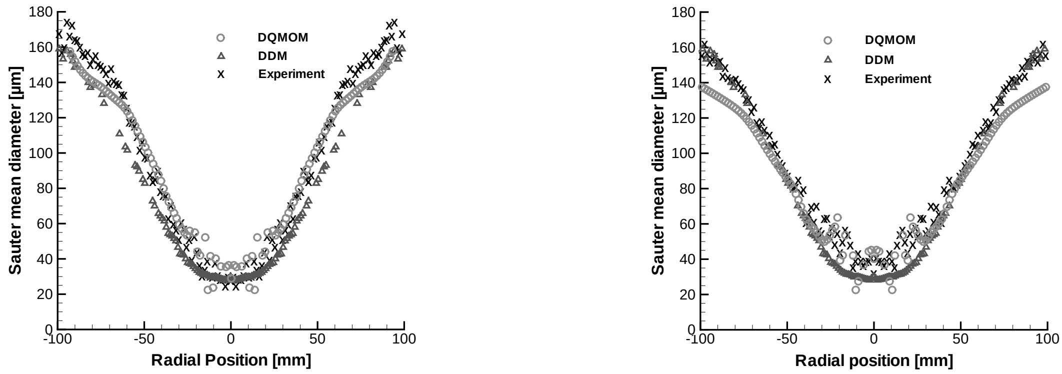

Figure 1. Radial profiles of Sauter mean diameter at cross sections of 0.12 m and 0.16 m away from nozzle exit.

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