Simulation of flow with spray closely to the air-blast injector: stochastic immersed body approach combined with LES

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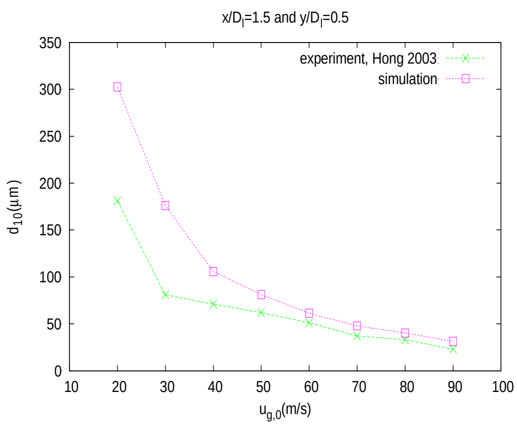
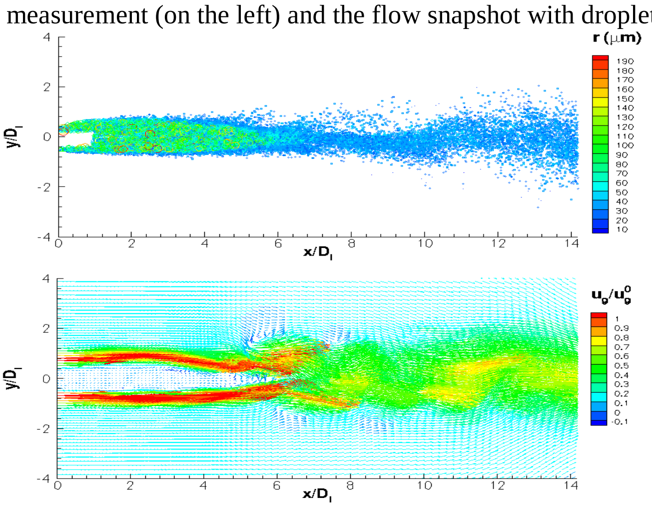
Abstract

In this paper, the new extension to the stochastic simulation of primary air-blast atomization is introduced, and is assessed by comparison with measurements. The idea of this extension is as follows. In LES of the gas flow, the primary atomization zone (liquid core, network of filaments and detached primary blobs) is viewed as immersed porous solid body with the stochastic structure. Namely, such a solid body is flowing with the inlet parameters for the liquid jet, and it is changing randomly its configuration. The statistics of configuration of this immersed body are used as boundary conditions in LES of the gas flow, thereby it is assumed that the jet fragmentation process is faster than typical time change scale in the gas flow. The statistical structure of the immersed body is defined by specifically introduced stochastic particles, moving in the space, and identifying the random position and curvature of the interface between the liquid and the gas. As it was previously in this approach, the simulation of position of such a particle is based on statistical universalities of fragmentation under scaling symmetry. To this end, the Langevin-type equation is derived and is simulated. Additionally, to each moving stochastic particle, we attribute now the random outwards normal to the interface. Thereby not only the random position of interface is simulated, but also its curvature. The statistics of curvature give statistics of the opening spray angle, and distribution of stripped blobs. For stochastic simulation of the outwards normal, the relaxation towards isotropy is suggested, along with propagation of spray in the down-stream direction. The inter-blob collisions in the primary atomisation zone are also introduced by analogy with standard kinetic approach for the ideal gas. Different closures are proposed for “statistical temperature” of blobs. The sensibility of this approach to the choice of mesh was analyzed. This numerical approach is assessed by comparison with experimental study of air-blast atomization, which was performed in LEGI (Grenoble, France). First, the computation showed a quite good prediction of the liquid core length; the predicted droplet’s velocity-and-size statistics (the mean and variance) at different distances from the center plane, and at different distances from the nozzle orifice, are predicted also being relatively close to measurements. The influence of different inlet conditions (different gas velocity at the constant gas-to-liquid momentum ratio, as well as the different gas-to-liquid momentum ratio) was also assessed by comparison with experiment. Second, two qualitative effects were observed. The first one is the presence of the recirculation zone in the front of the liquid core, emphasized previously in the experimental study. The flapping of the liquid core and bursting in the droplets production were observed correlated with the periodic existence of this recirculation zone. The second effect is decreasing of transversal gradient of the velocity with increasing of the gas-to-liquid momentum ratio. Increasing of the gas-to-liquid momentum ratio leads to more intensive atomization process, thereby smearing the velocity field. It was emphasized that such effect may influence the scalar mixing (concentration/temperature) in the close to injector region.
Figure: Comparison of the droplet mean size with measurement (on the left) and the flow snapshot with droplets





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