Numerical Study of Dense Turbulent Sprays using a Coupling of the Direct Quadrature Method of Moments with an Eulerian Multi-Size Moment Model

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Abstract

The polydisperse spray character of the injected liquid fuel predominantly influences the mixing of oxidizer and fuel vapour and, consequently, the flame structure in combustion processes, considerably affecting combustion efficiency and emissions in IC-engines and gas turbines. Especially due to increasing fuel prices and stronger emissions regulations, there is a need for a reliable numerical tool to accurately describe and optimize the dense spray behavior in modern engines.

This contribution aims at including droplet-droplet interactions into an Eulerian framework using the Direct Quadrature based Sectional Method of Moments (DQbSMOM), a novel hybrid approach which combines the Direct Quadrature Method of Moments (DQMOM), proposed by Fox et al. [1], with a Sectional Method (SM). This is made possible by approximating the number density function (NDF) through the Maximal Entropy formalism in order to calculate the droplet coalescence term, and by adopting the Eulerian Multi-Size Moment model (EMSM), proposed by Massot et al. [2], to describe evaporating droplet polydispersity. The EMSM model provides not only an accurate prediction of the evaporative flux, but also the possibility to couple DQMOM with a SM, once the moment flux between two sections can be calculated. The major advantage of this hybrid approach is a higher accuracy related to convective transport and drag. Among the advantages of the Eulerian approach are a lower computational cost through optimal parallel computing and a straightforward liquid-gas phase coupling.

To assess the designed tool, numerical results are compared to Phase Doppler Anemometry (PDA) measurements of a hollow-cone water spray as experimentally investigated by Rüger et al. [3]. The experiment provides comprehensive validation data that include gas velocities, droplet size distribution and droplet velocities. Turbulence of the disperse phase is captured by two different k-ϵ based models. Transient simulations using the standard DQMOM and the DQbSMOM with different number of sections were performed to assess the predictability of the suggested numerical model.

Satisfactory agreement is observed with increasing number of sections, allowing a more accurate prediction of droplet dispersion. Figure 1 illustrates that, by considering just 3 sections, the results are considerably more accurate than the standard DQMOM, with one section. The importance of droplet coalescence can be seen in figure 2.

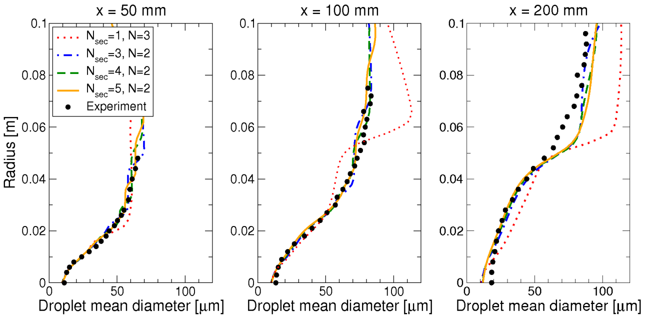

Figure 1. Droplet mean diameter over different measurement profiles in radial direction.

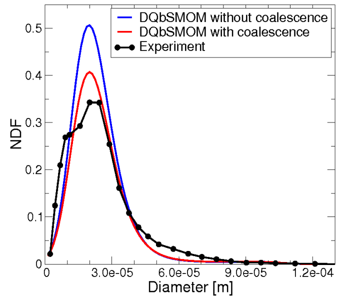

Figure 2. Local droplet diameter distribution at (x,y) = (50mm, 10mm).

References

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[3] Rüger, M., Hohmann, S., Sommerfeld, M., Kohnen, G., *Atomization and Sprays* 10:47-81 (2000).

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