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COLLISIONAL TRANSPORT PHENOMENA IN DENSE SPRAYS

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ABSTRACT In dense liquid sprays, droplet collisions make a major contribution to energy, mass and momentum transfer. Contrary to other transport processes that occur at the boundary between the gaseous and the disperse phase, droplet collisions occur within the disperse phase and thus are a highly efficient transport mechanism. Existing studies show the influence of collisions on flow properties such as drop size distributions or spray penetration. The present study presents a complementary evaluation of collisional mass, energy and momentum transfer and thus gives a detailed insight into the collisional transport phenomena in the disperse phase.

In previous studies (Pischke et. al., 2012a,b), the authors presented a high resolution collision algorithm for Lagrangian stochastic parcel simulations, which is applicable to highly anisotropic sprays and converges at second order even in the presence of strong velocity gradients, where other algorithms fail. The algorithm was validated against analytical validation cases and numerical experiments, delivering converged results of collision rates, momentum transfer and energy dissipation.

Based on the present algorithm, exemplary LES studies of turbulent full-cone sprays were conducted to check the applicability to turbulent mixture formation processes (Pischke, 2014). Within these exemplary studies, collisional transport processes can be tracked at high temporal and spatial resolution.

Results indicate that collisional transport processes lead to momentum transfer rates as high as the overall momentum injected, and dissipate up to 25% of the overall kinetic energy of the disperse phase. Collisions can be tracked back to specific regions of the full-cone spray, (i) the atomization region, (ii) regions of strong curvature such as laminar vortices or turbulent eddies, and (iii) regions of strong deceleration such as the spray tip.

Within these regions, very characteristic collision regimes are predominant, indicating that permanent coalescences are responsible for mass, energy and momentum transfer, while non-permanent coalescences lead to kinetic energy dissipation. Based on recent collision models (Munnannur and Reitz, 2007), further evaluation shows that mass, energy and momentum transfer occur at low Weber number collisions, while high Weber number collisions are strongly dissipative.

The present results help to understand the role of collisional transport processes in liquid sprays, underline the importance of accurate collision modeling in disperse phase simulations, and support future modeling efforts with a valuable database.

REFERENCES

Munnannur, A., Reitz, R.D., 2007b. A new predictive model for fragmenting and non-fragmenting binary droplet collisions. Int. J. Multiphase Flow 33, 873–896.

Pischke, P., Cordes, D., Kneer, R., 2012b. A collision algorithm for anisotropic disperse flows based on ellipsoidal parcel representations. Int. J. Multiphase Flow 38, 1–16.

Pischke, P., Cordes, D., Kneer, R., 2012c. The velocity decomposition method for second-order accuracy in stochastic parcel simulations. Int. J. Multiphase Flow 47, 160–170.

Pischke, P. 2014. Modeling of collisional transport processes in spray dynamics. Dissertation, RWTH Aachen University.