Simulation of Primary Breakup for Diesel Spray with Phase Transition

P. Zeng*[1], B. Binninger[1], P. Peters[1] and M. Herrmann[2]

[1]Institute of Combustion Technology
RWTH Aachen University, Germany
[2]Department of Mechanical and Aerospace Engineering
Arizona State University, Tempe, Arizona, USA

Diesel spray breakup and evaporation determine the characteristics of the fuel-air mixing for mixture-fraction based combustion models. An accurate spray breakup model is a key point for their predictability, especially primary breakup. Different from the popular droplet-particle based Langragian models, we resolve the liquid phase in Eulerian frame. In addition, a level-set method is employed to capture the two-phase flow interface, including surface tension force. The phase transition is taken into account by introducing surface regression velocity into the level-set transport equation. Through 3D direct numerical simulation (DNS), we can have insight in the formation of ligaments and droplets for diesel direct injection. As experimental results are still difficult to obtain for dense spray, the simulation result reveals the spray primary breakup with the help of modern supercomputers in first principle.

Refined level-set grid method

Spray primary breakup is a multiscale problem that involves a wide range of time and length scales. In order to balance the efficiency and accuracy of the simulation model, the Refined Level-Set Grid (RLSG) method has been designed [1]. As Fig. 1 illustrates, the interface evolution level-set equation is solved by using the RLSG method on an auxiliary, high-resolution equidistant Cartesian grid, while the Navier-Stokes equations governing both gaseous and liquid phase are solved on their own unstructured computational grid.

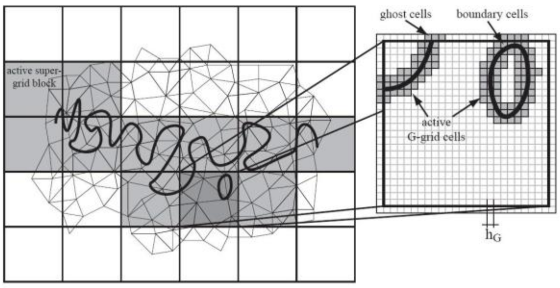

Figure 1: Refined level-set grid method [1]

Summary and Outlook

Figure 2 shows snapshots of the turbulent liquid jet and droplets generated by primary breakup [2]. In this work, an extension of the level-set method for primary breakup with phase transition is presented. The surface regression velocity is introduced and the interface evolution equation is derived. This model is applied on a direct numerical simulation of a turbulent diesel injection. Though there are many numerical uncertainties, preliminary results show promise in regard to a further understanding of the physical process of atomization with evaporation effect. The mathematical model and the DNS solution presented here will provide the frame for a statistical simulation of the primary breakup, within the large eddy simulation (LES) will be done in the future.

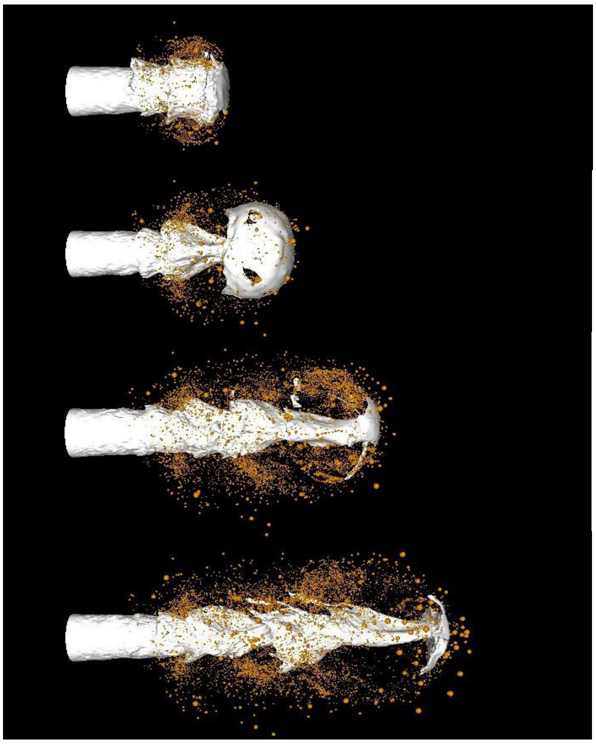

Figure 2: Snapshots; from top to bottom: t = 4µs, t = 6µs, t = 8µs, t = 10µs [2]

References

[1] M. Herrmann. A balanced force refined level set grid method for two- phase flows on unstructured flow solver grids. *J. Comput. Phys.*, 227:2674–2706, 2008.

[2] P. Zeng, B. Binninger, N. Peters and M. Herrmann. Simulation of primary breakup for diesel spray with phase transition. *11th ICLASS International Conference on Liquid Atomization and Spray Systems*, Accepted, 2009.

* Corresponding author: p.zeng@itv.rwth-aachen.de
Towards Clean Diesel Engines, TCDE2009