reaction DESIGN

FORTÉ
Spray Modeling

Accurately capturing fuel injection, spray breakup and spray vaporization are important aspects of engine-design simulations for direct-injection engines. However, it is difficult to isolate the effects of spray behavior in a full engine simulation involving combustion, moving boundaries and complex turbulent flow. Spray-bomb experiments are an excellent method for isolating the spray behavior prior to engine design and analysis.

FORTÉ can be used to simulate spray-bomb experiments accounting for the key aspects of atomization, such as liquid-jet breakup, droplet formation, secondary breakup, droplet collisions, droplet coalescence and vaporization. The FORTÉ Simulation Package uses an advanced Kelvin Helmholtz-Rayleigh Taylor (KH-RT) spray model that simulates liquid breakup, secondary droplet breakup, distribution and evaporation. Together with the gas-jet model, which provides accurate gas-jet entrainment calculations without requiring mesh refinement around the spray, the FORTÉ spray model provides results that are insensitive to mesh resolution or simulation time step.

Setting up a Spray-Bomb Case with FORTÉ

In this case, a single-component fuel is injected into a cylindrical chamber. The fuel is injected from a single solid-cone injector, where the nozzle hole is located on the wall and the injection is directed towards the center of the chamber (Figure 1). The initial gas in the chamber is a blend of N_2, CO_2, and H_2O, such that the mixture is non-reacting. As the intention of this example is to represent diesel-fuel injection, we use the physical properties of *n*-tetradecane to represent the fuel. This combination of chemistry model being represented by one fuel surrogate (in this case, *n*-heptane) while the physical model is represented by another fuel surrogate (in this case, *n*-tetradecane) is an approach often taken in simulating diesel engine combustion. In this way, the spray-bomb simulation comparisons to experiment can be used to verify the behavior of the surrogate model approach as it will be used in a combustion simulation.

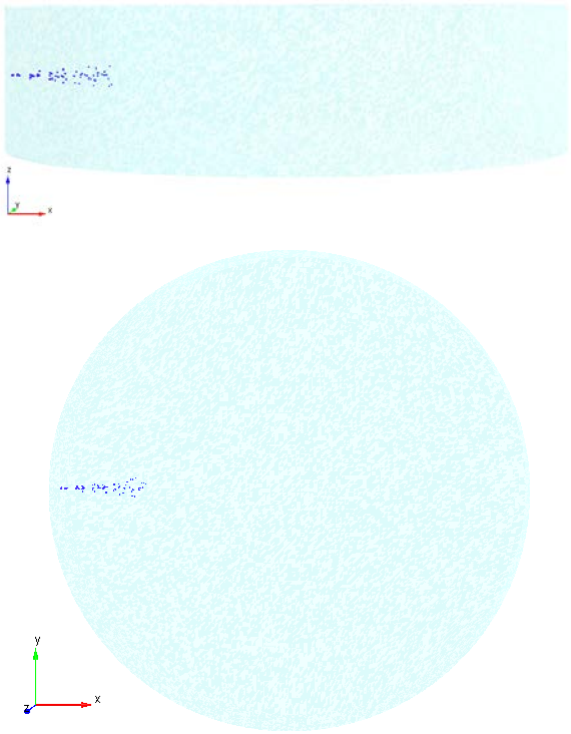

Figure 1. Spray-bomb simulation geometry showing injection at left.

See the Results

The spray-bomb test case was run with three mesh sizes (1 mm, 2 mm and 3 mm) and then compared against experimental data of Naber and Siebers.[1] The experimental data provided consisted of liquid penetration depth for the test spray. These data show a penetration depth of 22.6 mm, as is shown in Figure 2, *Mesh sensitivity on spray penetration depth*. The simulation results show good agreement with the spray penetration depth, as is also seen in Figure 2. These results also show that the spray is relatively insensitive to the mesh for the three mesh sizes considered.

Another interesting feature is to look at the how the droplet mass and vapor mass evolve during the simulation time. These results are shown in Figure 3, where the mesh is also shown to be insensitive to the mesh size, even with the coarsest mesh. An automated parameter study was used to investigate the impact of chamber pressure on penetration depth (Figure 4). The spray penetration is decreased as the ambient pressure increases due to the increased chamber gas density and drag.

[1] Naber, J. D. and Siebers, D. L., "Effects of Gas Density and Vaporization on Penetration and Dispersion of Diesel Sprays", SAE Technical Paper 960034, 1996.

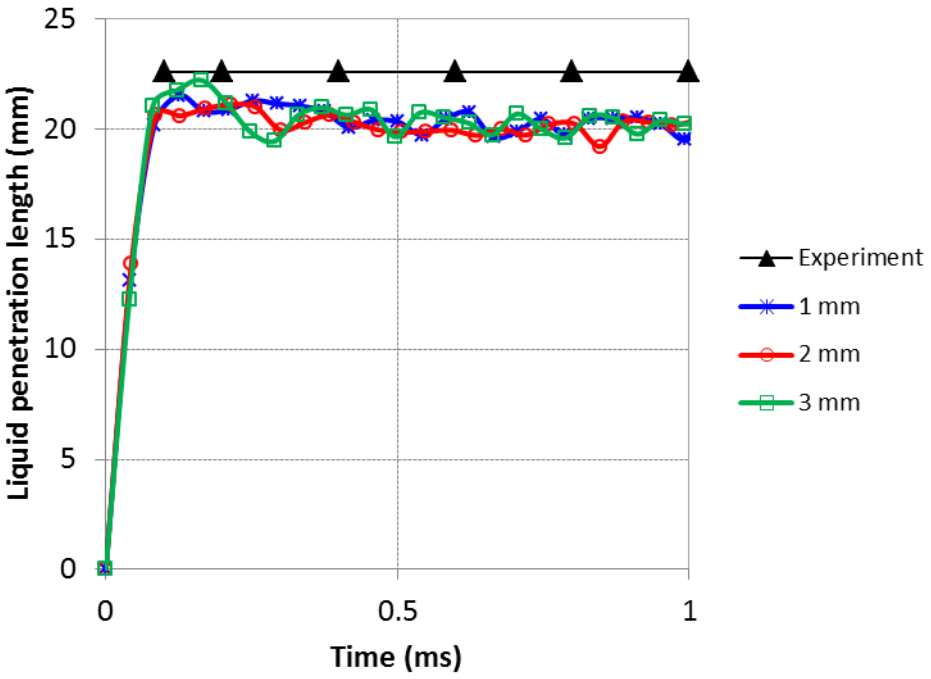

Figure 2. Mesh sensitivity on spray penetration depth.

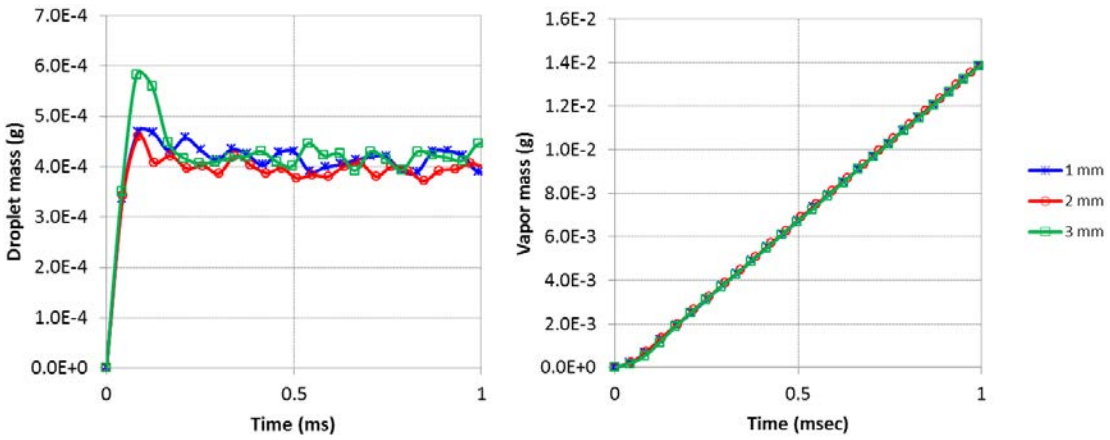

Figure 3. Mesh sensitivity on droplet mass and vapor mass.

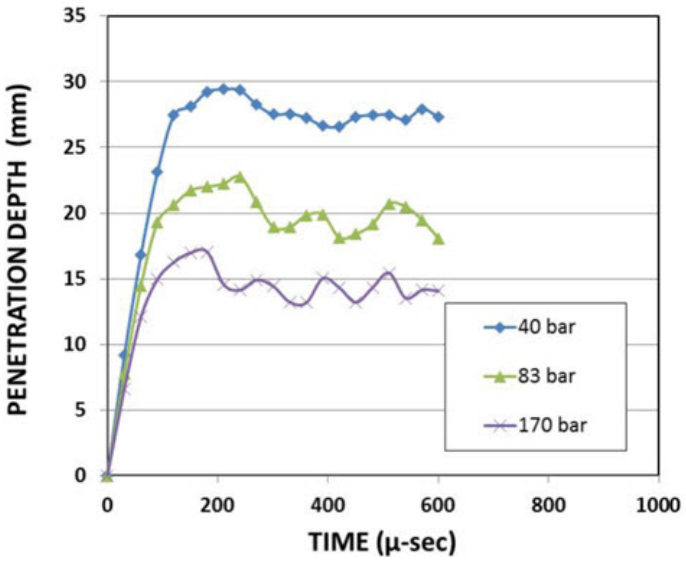

Figure 4. Results of automated parameter study on ambient pressure in the spray bomb.