Numerical and Experimental Investigation of Fuel Spray Behaviour in Very High Density Environment Using LES

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Abstract

An effective way to increase the specific power from engines is to increase the maximum cylinder pressure. However, this also increases the gas density which has significant effect to the fuel spray evolution. In this study, experimental data from room temperature conditions at gas density of 39 kg/m^3 and at very high gas density of 115 kg/m^3 representing cylinder density at 300bar pressure conditions is compared to fuel spray large eddy simulations (LES). Special attention is put to the analysis of turbulence on local basis but also on a spray-induced volume basis. It is observed that several realistic features that can be seen in experimental sprays could be identified from the simulated fuel sprays. These include local turbulent structures, droplet clustering, and non-symmetric features. The computational model was also able to produce a range of frequencies and small scale structures which are needed from a properly working LES simulation. The spray opening angles as well as the droplet sizes were well captured with the LES model whereas the trend for the spray penetration was somewhat too long. The main reason for this is believed to be the mesh resolution that did not produce quite enough momentum spreading close to the nozzle.

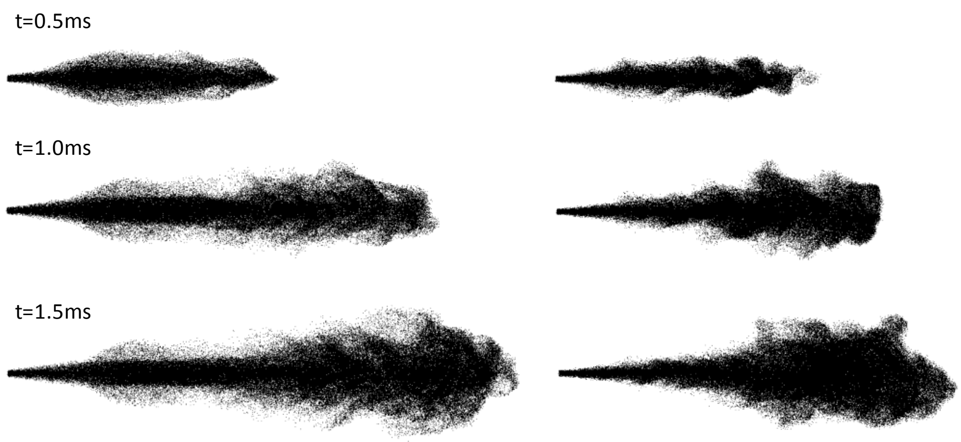

Figure. Fuel sprays at different times. Left: gas density is 39 kg/m^3. Right: gas density is 115 kg/m^3.

Conclusions

LES simulations and experiments have been carried out at two gas densities, 39 kg/m^3, and in very high gas density of 115 kg/m^3. It is observed that:

- The computed sprays in both normal 39 kg/m^3 gas density and in very high 115 kg/m^3 gas density have many realistic features that resemble those observed in experimental sprays. These include local turbulent structures, droplet clusters (preferential concentrations), voids, and non-symmetric features.
- LES was able to resolve large spectrum of frequencies and small scale structures which is necessary for a LES model to work properly.
- The production of turbulence was analyzed on cell basis and on a spray-induced volume basis. It was observed that the portion of the resolved scales was relatively high indicating good quality LES.
- The global parameters such as droplet sizes and opening angles were relatively well captured but the trend in the predicted spray penetration is too long. The main reason for this is in the momentum coupling between the gas phase and the dispersed phase. The mesh used in the current study is not fine enough leading to somewhat insufficient momentum spreading and turbulence production close to the nozzle. The calculated velocity boundary condition at the nozzle hole (z=0) is given as such at $z=6d_n$ assuming negligible velocity decrease during the distance of $6d_n$. This is because up to $z=6d_n$ the liquid volume fraction is high leading to reduced momentum transfer between the phases.