Effect of split-injection strategies on spray characteristics studied for an outward opening pintle-type DISI piezo-injector

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Abstract

Direct Injection Spark Ignition (DISI) combustion engines provide a promising technology to minimize fuel consumption and pollutant emissions. Especially, piezo-actuated outward opening pintle nozzles show advantages in generating a very fine and reproducible hollow-cone spray [1] for a fast mixture formation. This is currently of great interest for reduction of soot formation during mixing-controlled combustion of spray-guided DISI engines. Furthermore, the precise control of the injection quantity and timing is favourable to realize high-efficiency combustion. Split injection strategies can be used to extend the stratified combustion regime and to control the mixing timing. In this study, the liquid spray structure was analyzed for single injection and different split injection schemes in an injection chamber for a piezo-actuated outward opening pintle nozzle (Continental). Laser-based techniques such as planar Mie-Scattering and phase Doppler anemometry were used and a numerical spray model was set up applying the 3D-CFD-Code OpenFOAM. The injection quantity was 12 mg/injection (dwell time: 400 µs, injection pressure: 20 MPa, fuel: iso-octane) representing a part-load condition. The ambient conditions were 1.5 MPa at 283 K and the fuel temperature was set to 263 K for a non-evaporating spray investigation. First, the numerical model was calibrated for the single injection regarding spray shape, droplet size distribution as well as size and position of the recirculation zones (see Figure 1). The simulation shows very good agreement and was validated for the different split injection schemes at constant injected mass. The effects of variable pulse duration of the first and second injection as well as the delay time between the pulses on the spray structure were studied in comparison to the single injection. For all tested double-injection schemes, the spray length decreases compared to the single injection spray whereas the radial penetration increases. The average droplet sizes are very similar for the single and split injection scheme, the Sauter Mean Diameters (SMD) were around 26 µm due to collision and coalescence effects. Longer pulse duration of the first injection strongly increases the early axial and radial spray penetration due to the larger initial spray momentum, whereas the delay and duration of the second pulse determines the number of vortices and their shapes as well as the radial spray propagation at later times after start of injection.

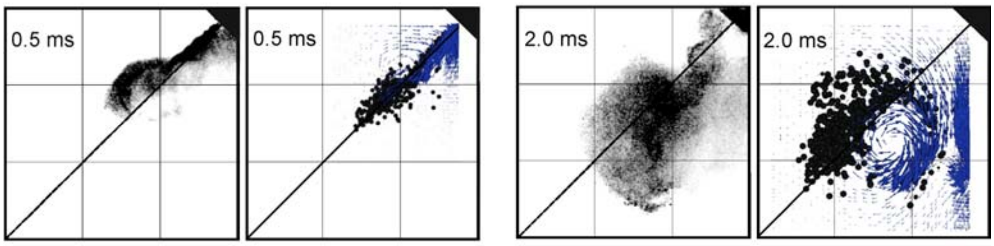

Figure 1: Comparison of the spray shape for single pulse injection, left: 2D Mie-scattering image (single-shot), right: simulation of the flow field (arrows) and the liquid phase (black dots)

References

[1] Zigan, L., Schmitz, I., Flügel, A., Wensing, M., and Leipertz, A., Structure of evaporating single- and multi-component fuel sprays for 2nd generation gasoline direct injection. Fuel 90 (2011), p. 348–363

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