Measurement of temperature and vapour distribution in an evaporating DISI-spray under engine relevant conditions using two-line excitation laser-induced fluorescence

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Abstract

The main objective in the development of modern IC-engines is the reduction of fuel consumption and pollutant emission. Direct-Injection Spark-Ignition (DISI) strategies are commonly used and especially spray-guided concepts (SG-DISI) offer a high potential to reduce fuel consumption. Higher compression ratios are possible due to the evaporation cooling of the spray, which reduces the in-cylinder temperature so that engine knock is minimized. However, the mixture is not homogeneous through the combustion chamber, and therefore, local hot spots or low temperature regions can appear. The temperature distribution determines evaporation and ignition behavior. Furthermore, it is strongly affected by the fuel evaporation properties, which are different for modern fuels compared to gasoline. Thus, a spatial and temporal resolved measurement of the temperature and fuel concentration during injection is required to locally resolve vapor distribution and cooling in the spray.

Planar laser-induced fluorescence (PLIF) is an approved method to measure fuel vapor distribution under engine relevant conditions. In this study this technique is optimized for simultaneous vapor concentration and temperature measurements in DISI sprays. The fluorescence tracer 3-pentanone is added to a non-fluorescent surrogate fuel such as iso-octane. A multi-hole injector spray is excited quasi-simultaneously by two excimer lasers (two-line LIF) with the wavelengths of 248 nm and 308 nm. The signals are recorded with one double-shutter ICCD-camera. The temperature field can be calculated from the ratio of these signals, and afterwards the vapor concentration can be determined from a single signal with the known temperature. As the signal intensity of the tracer depends among other factors strongly on temperature, pressure and concentration, it has to be well calibrated. The calibration of the 3-pentanone is carried out in a high temperature / high pressure flow cell .

The spray measurements are conducted in a high temperature / high pressure injection chamber, where engine relevant conditions up to 1000 K and 10 MPa can be adjusted. A 6-hole solenoid-injector is used for the measurements, iso-octane with 20% (by volume) 3-pentanone as tracer is investigated. The figure exemplary shows the averaged temperature over 32 single measurements for 2.5 ms after visual start of injection (vSOI) and the measured and simulated profile at 40 mm distance from the nozzle for 2.5 ms and 3 ms after vSOI. The injection duration is 1 ms, the injection presure is 10 MPa and the chamber temperature and pressure are kept at 673 K and 0.8 MPa, respectively. At this point, a maximum cooling of about 132 K in the center of the spray is measured. To validate the measurement the temperature and concentration are compared to the results of a Computational Fluid Dynamics (CFD) spray model. The model is set up with OpenFoam 1.5 and uses a transient Reynolds-Averaged Navier-Stokes (RANS) approach with all relevant submodels for a realistic spray representation. The model is calibrated regarding spray shape and propagation as well as droplet size distribution for iso-octane. Additionally, an error analysis is carried out. For the averaged measurements a temperature error of 3.8% and mass fraction error of 5.5% are estimated.

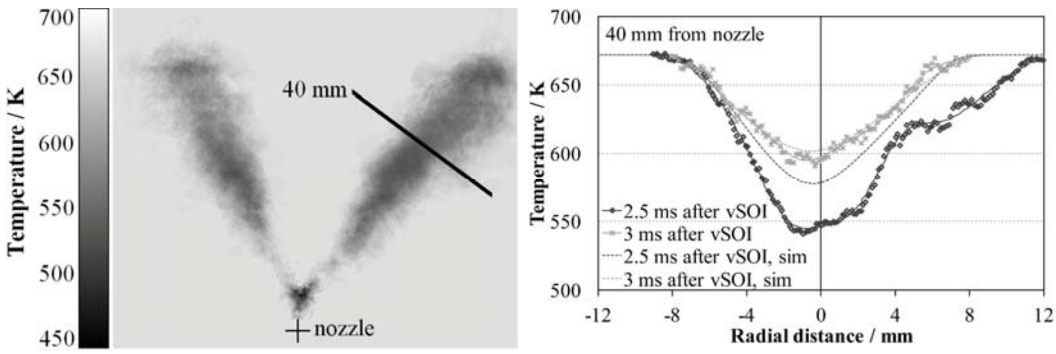

Figure: Temperature of iso-octane spray 2 ms after vSOI (left) and profile at 40 mm distance (right)

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