Dispersion of a fuel spray in a heated channel with controlled turbulence: characterization of droplet temperature and fuel vapour distribution.

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Abstract

Designing new low-emission combustors requires the development of computational codes with high predictive capabilities. Numerical models used in these numerical simulations must be validated against experimental reference cases where the different parameters of interest can be measured and controlled.

This contribution presents experiments where a fuel spray with a known composition is injected in a heated channel where homogeneous and isotropic turbulence is developed. Droplet size and velocity distributions as well as the characteristics of turbulence in the gas flowfield were previously measured. The liquid fuel consists of different mixtures mainly composed of n-decane and a fraction of 3-pentanone varying from 0 to 15 % in volume. Air inlet temperature is 560 K, bulk-flow velocity 2 m/s and turbulence rate about 25 %.

Two laser-based diagnostics are implemented on this experiment in order to characterize both the liquid and the gas phases.

Droplet temperature is first measured with the two-color laser-induced fluorescence technique which requires to dissolve a temperature-sensitive fluorescent tracer in the liquid fuel. The fluorescence, induced by a CW argon laser tuned at 514.5 nm, is detected over two spectral bands for which the temperature sensitivity is sufficiently different. The ratio of the fluorescence signals from both bands depends only on temperature. A preliminary study has clearly pointed out additional effects of the size polydispersion together with the fuel composition on the fluorescence signal. This study was used to derive a strategy in order to get rid of these phenomena in the present experiments. Droplet temperature profiles were recorded along the channel axis together with radial profiles at different distances from the injector. A strong increase of droplet temperature is observed immediately after injection, followed by a smoother heating at larger axial distance. Adding a little amount of a more volatile component (3-pentanone) leads to a two-stage heating. 3-pentanone evaporates first, the initial increase being followed by a plateau where it all vaporises. At later stages, this temperature profile tends to become similar to that of pure n-decane.

In a second step, the spatial distribution of 3-pentanone vapour in the gas phase at various distances from the injector is determined by means of planar laser-induced fluorescence using a frequency-quadrupled output of a Nd:YAG laser at 266 mm. Fluorescence is recorded by an intensified CCD camera equipped with a high-pass optical filter to collect signals at wavelength larger than 320 nm. Evolution of fuel vapour concentration with distance from the injector is observed due to spray spreading and droplet evaporation. Additionally, local flow structures can be visualized and the influence of vortices on droplet trajectories can be evidenced.

Key words: spray, evaporation, turbulence, droplet temperature, bicomponent, gas phase, LIF, PLIF

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