Droplet internal temperature field measurements. Comparison to modeling and numerical simulation

G. Castanet\textsuperscript{1,2}, A. Labergue\textsuperscript{1,2}, B. Frackowiak\textsuperscript{3}, C. Tropea\textsuperscript{3}, F. Lemoine\textsuperscript{1,2,*}

1: Université de Lorraine, LEMTA, UMR 7563, France
2: CNRS, LEMTA, UMR 7563, France
3: Institute of Fluid Mechanics and Aerodynamics, Center of Smart Interfaces, Technische Universität Darmstadt, Germany.

Keywords: LIF, droplet evaporation, temperature measurement

Modeling of spray evaporation is required to optimize combustion chambers performances and to reduce pollutant emissions. As a fuel droplet enters in the combustion chamber, the droplet is heated and evaporates. The fuel vapor mixes with the oxidizer, burns and finally heat is released. The accuracy of the simulation tools in this field is highly related to the level of knowledge placed in the description of the elementary phenomena. Widely used models for the transient heating of the droplets are derived from the case of the isolated droplet and consider a purely radial distribution for the temperature within the droplet. A more refine model supposes that the velocity field inside the droplet corresponds to a Hill vortex. Following this assumption, the velocity in the vortex can be related to the friction drag coefficient (Abramzon and Sirignano, 1989). However, in the presence of evaporation and wake effects induced by neighbouring droplets, no model is available for the friction force acting on the surface of the droplets. Moreover, several works based on Direct Numerical Simulation (DNS) have enlightened that thermo-capillarity effect (Marangoni effect) can induce internal flow in the case of isolated droplet (Niazmand et al., 1994). However, these simulations require being extended to interacting droplets and validated by refined measurements. In this study, mono-sized droplets are injected periodically into a flame sustained by the vapour released by the droplets (figure 1).

The surface in contact with hot air is the first region to be heated. Then due to internal circulation, heat is transported to the bottom of the droplet (trailing edge region) and finally it goes up into the core of the droplet. Temperature fields have been used to estimate the magnitude of the sliding velocity at the liquid-gas interface, when the streamlines within the droplets are assumed to follow the Hill vortex pattern. Experiments reveal how the magnitude of the internal velocity decreases with the distance between the droplets. Aerodynamic interaction phenomena have thus a dominant role on the droplet internal velocity field participating in the heat advection within the droplet.

Finally, comparisons between the experimental results and DNS point out the importance of the thermo-capillarity stress caused by the non-uniform temperature at the droplet surface. Taking into account the Marangoni effect is required to obtain a good agreement between experimental temperature maps and the simulation by DNS. The Marangoni effect is responsible for a significant slowdown of the internal flow during the heating of the droplet.

![Fig. 1 A monodisperse droplet stream in a flame](image)

The two-colour laser-induced fluorescence thermometry is then used to characterize the temperature distribution within the droplets (Castanet and Lemoine, 2007). The effect of the liquid viscosity is examined by testing different fuels (acetone, ethanol, heptane, decane, dodecane). The distance between consecutive droplets can be also adjusted to modify the degree of interaction between the droplets.

Measurements agree qualitatively well with what would be expected from heat advection by a Hill vortex (figure 2).

![Fig. 2 Example of internal temperature field](image)

![Fig. 3 Influence of the Marangoni effect (a: simulation with Marangoni effect, b: without Marangoni effect)](image)

References

