A two-color Planar LIF technique to visualize the temperature of droplets impinging onto a heated wall

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Liquid cooling is widely used in application areas where the required dissipation power is very large due to its particularly high cooling efficiency when the liquid vaporizes. While pool boiling and jet impingement techniques have satisfactorily provided high heat dissipation rates, they generally consumes massive quantities of water and energy and they fail to insure uniform and controlled surface heat flux. These drawbacks are much less of a problem when dealing with sprays.

In the present study, the emphasis is placed into the measurement of the liquid variation in temperature when droplets interact with a hot solid surface, typically above the Leidenfrost temperature where a vapor film forms quasi-instantaneously between the droplet and the wall. This measurement is of particular importance to determine the part of the energy that is removed by the sensible heat of the liquid. The case of a water droplet stream impacting onto a smooth heated plate made of nickel is considered. The two-color laser-induced fluorescence technique (2cLIF) is used to measure the droplet temperature (Lavielle et al. 2001). In this two-color one-single dye approach, the emissions from two different spectral bands with different temperature sensitivities are utilized. The ratio of the intensities of these two bands allows eliminating the dependence of the fluorescence signal to the tracer concentration, the incident laser intensity and the collection volume that are particularly difficult to control in case of moving droplets.

Recently, the 2cLIF thermometry was used to determine the droplet change in temperature during their impingement on a heated solid surface (Castanet et al. 2009). Point-wise measurements were performed near the location of the droplet impact to determine the average heating. Presently, an extension of the technique to planar laser induced fluorescence (PLIF) is described.

Fig. 1 Illustration of temperature measurements in the rebound regime.

PLIF imagery has already been used to visualize the temperature in single phase liquid flows (Sakakibara et al. 2004) but its implementation to droplets has been very limited.

The imagery system is designed for observing single drop impacts onto a hot wall with a field of view limited to a few millimeter squares. It is composed with 2 CCD camera for the detection of the two spectral bands and a long-distance microscope. The focus is placed first on the description of the technique development: the selection of a suitable tracer having a high temperature sensitivity, its temperature calibration and the correction for the non-linearity of the response of the measurement system. Because of the particularly reduced size of the measurement zone, an original procedure for the pixel-by-pixel correspondence of the camera images had to be developed.

After several tests carried out on droplets in temperature controlled conditions, the feasibility of the method is finally demonstrated in the case of droplets impinging on a heated wall. Depending on the wall temperature and the Weber number of the droplets, several regimes of impact can be observed with an high-speed camera such as rebound (fig. 1), and splashing (fig. 2). Results show that the droplet heating is function of the impact conditions and the impact regime.

Fig. 2 Illustration of temperature measurement in case of a splashing

References


4.3.2.