Energy balance for single or multiple droplet chains impinging onto a hot slab in the Leidenfrost regime

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Abstract

This work aims at estimating the energy balance during a single droplet chain or multiple droplet chains interaction with a hot wall whose initial temperature is above the Leidenfrost point. The corresponding experimental data are required for validating submodels for heat transfer between a hot wall and sprays. these physical submodels are subsequently used in CFD modeling.

In the Leidenfrost regime, impinging droplets can experience only three different regimes : perfect bouncing, bouncing with a satellite formation and splashing. Modeling heat transfer in these regimes requires the knowledge of several parameters such as the spreading diameter, heat transfer at the wall, the thickness of the vapour layer, its temperature as well as the liquid heating during the impingment and the evaporation rate. In the splashing regime, data about secondary droplets are also required. Up to now, no experimental data base giving all these parameters are available because of the difficulty to measure simultaneously all these parameters. In this experimental work, some of these parameters have been measured simultaneously during the interaction of the droplet with the heated wall while other ones have been estimated by means of an energy balance.

A monodisperse droplet chain (diameter 80-220µm) is interacting with a hot wall above the Leidenfrost point. A dedicated experimental set-up designed for characterizing heat transfer during the impingement was developped. The slab is a thin nickel plate heated by electro-magnetic induction up to a temperature above the Leidenfrost point. The temperature of the rear face of the nickel sample is measured using an infrared camera and the heat removed from the wall and caused by the presence of the droplets is estimated using a semi-analytical inverse heat conduction model. At the same time, the temperature of the droplets is measured using the two-colour Laser-Induced Fluorescence thermometry which has been extended to imagery for the purpose of these experiments. The measurements of the variation in the droplet temperature occurring during the impact allows determining the liquid sensible heat. Coupling these two measurement techniques allows to estimate the heat flux associated to liquid evaporation. The evaporated mass of the droplet during the impingment is derived from the energy budget of the impingment. A wide range of parameters were tested : Weber number, droplet diameter, droplet injection temperature, injection temperature, corresponding to the bouncing and splashing regimes. Finally, the preliminary results of multiple monodisperse droplets chains are presented. The database reveals that, in the case of small droplets, the cooling mechanism is mainly related to evaporation and the part of the sensible heat gained by the droplets increases as the droplet diameter increases.