Dynamical Interaction between a Droplet and a Wall Heated beyond the Leidenfrost Temperature

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Most nuclear power plants adopt spray systems as safety measures, considering that a spray can be represented by a collection of droplets, in this work we study the interaction between a single droplet and a hot wall. Our interest lies in the dynamic Leidenfrost effect, where the contact between an impacting droplet and a very hot wall is prevented by a vapor layer formed through the vaporization of the droplet. A simple model is proposed, consisting of an improved lumped approach based on Hermite-type approximations for integrals for the transient heat transfer in the droplet and the wall, an integral method to model the transient heat transfer in the vapor layer, and a lubrication approximation that considers the effects of inertia for the flow caused by the vaporization and the motion of the droplet [1]. The proposed model was implemented in the symbolic computing platform Mathematica® [2] and used to analyze the droplet dynamics considering different initial wall temperatures. Parametric studies were carried out to investigate the effects of initial droplet size and velocity on the interactions. The effects of wall material and its temperature variation were also evaluated by considering different materials and an isothermal case. As results, the behavior of the droplet is verified to change continuously over time until it takes-off from the wall just before complete vaporization. Furthermore, at the impact, more heat is removed from the wall by larger and faster droplets, and the cooling of the wall, which is inversely proportional to the thermal conductivity, showed negligible effects on the dynamics of the droplet.

Figures 1a,b,c show the typical behavior of a droplet for three wall temperatures. The droplet dynamics is divided into three stages: the rebound phase (a), the quasi-steady phase (b) and the take-off phase (c). The rebound phase goes from the moment the droplet is released until almost all of its kinetic energy is lost. In the quasi-steady phase the droplet is almost motionless, the only contribution to its motion being the vaporization. When the droplet becomes very small, it ascends from the wall, which corresponds to the take-off phase.

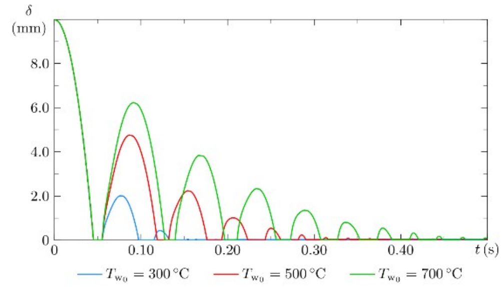

Figure 1a. Temporal variation of the droplet position: rebound phase.

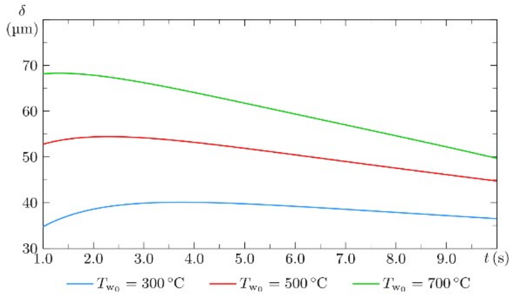

Figure 1b. Temporal variation of the droplet position: quasi-steady phase.

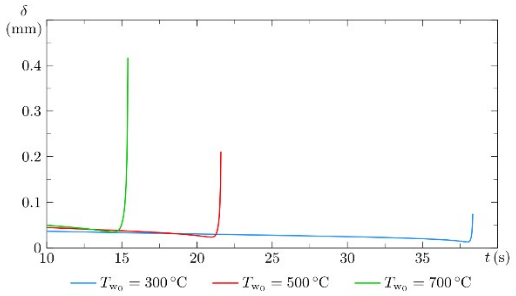

Figure 1c. Temporal variation of the droplet position: take-off phase.

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