Leidenfrost drops on liquid pools

L. Maquet, B. Darbois-Texier, A. Duchesne, M. Brandenbourger, and S. Dorbolo
GRASP, Physics Department,
Université de Liège, B-4000 Liège, Belgium.

B. Sobac, A. Rednikov, and P. Colinet
TIPs, Polytechnic school,
Université Libre de Bruxelles,
B-1000 Bruxelles, Belgium.

T. Truscott
Splash lab, Department of Mechanical and Aerospace Engineering,
Utah State University, Logan, Utah, U.S.A.
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As far as the eighteenth century, the phenomenon that is nowadays known as the Leidenfrost effect has always fascinated minds. This state where a drop levitates over a bed of its own vapour has shown a lot of interesting properties. In the 19$^{\text{th}}$ century, Boutigny even thought that it was a new state of matter and thought that it was crucial to describe the birth of the universe [1]. During the 20$^{\text{th}}$ century, most researchers focused on ways to supress this effect that significantly lowers the efficiency of the cooling of hot surfaces. Recently, the use of these drops have begun to show interesting possibilities such as the self-propulsion and transport of objects [2], or the organisation of particles [3, 4]. The preservation of this state seems more and more crucial.

Roughness has been shown to increase the Leidenfrost temperature, *i.e.* the temperature above which this effect takes place [5]. The idea of our work is then to use the smoothest substrate possible : a liquid pool. And indeed, we observed stable Leidenfrost drops with differences in temperature between the boiling point of the liquid of the drop and the temperature of the bath down to 1°C. This extraordinary behavior has been seen notably for ethanol drops on silicone oil baths. The shape of the drop and of the pool below the drop has been described with a model similar to a model of a Leidenfrost drop on solid substrate [6], with the addition of a Young-Laplace equation describing the surface of the pool. We also investigate the evaporation of these drops. It appears that the scalings for the evaporation are different from those applying in the case of a solid substrate. No transition between two regimes could be observed and the decrease of the radius of the drop with the time has been found to be linear.

We also observed that the viscosity of the pool has an impact on the Leidenfrost temperature. Indeed, no Leidenfrost drop has been observed on silicone oil pools with kinematic viscosity above 300 cSt. At high viscosities, we expect the recirculation to be less efficient in the pool. And as the drop cools down the pool, regeneration of the oil under the drop may be crucial for the drop to levitate above the pool. To understand the flows of oil inside the pool, we performed PIV experiments. We observe recirculation cells and velocities of the fluid at the surface of the the pool ranging typically from 0.01 to 0.1 m/s. However, the strongest concern brought by these experiments lies in the direction of these flows. Under ethanol drops, the oil at the surface goes towards the drop, but under drops made of HFE–7100, it goes away from the drop.

Finally, we also investigate impacts of HFE–7100 drops on hot liquid baths. We observe four regimes when we increase the Weber number. First, the bouncing of the drop that stays in the Leidenfrost state for seconds after its stabilization on the surface of the bath. Second, the creation of an anti-bubble, *i.e.* a drop in a shell of vapour surrounded by the liquid of the pool (see Fig. 1(b)). Third, a regime where the pinch-off that creates the anti-bubble destabilize the vapor film, leading to a a contact of the drop with the pool and a quick evaporation. Finally, when the drop comes too fast, the vapour film has no time to be created. The drop then contacts the substrate, spreads quickly on the pool, and forms an hemispherical cavity. We measure the critical Weber numbers for the transitions between these regimes, varying the size of the drop and the viscosity of the pool.

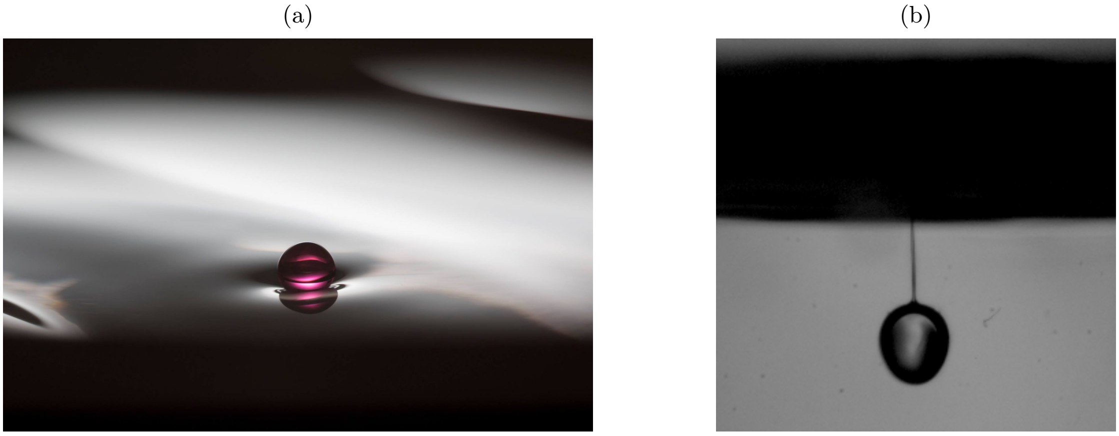

FIG. 1: (a) Ethanol drop in the Leidenfrost state over a bath of silicone oil. (Image credit : Florence Cavagnon) (b) An anti-bubble made by impacting a drop of HFE in liquid bath of silicone oil at 140°C.

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