Velocities and size of outgoing droplets after impact on a wall heated above the Leidenfrost temperature

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Abstract

The interactions between sprays and hot walls occur in a wide variety of applications like spray cooling in the metal processing industry or the direct injection engines. However, their industrial integration remains difficult due to poor understanding of the flow and heat transfer characteristics. In the present study, the emphasis is placed on the impact of droplets onto a wall above the Leidenfrost temperature. In the experiments, chains of equally spaced and mono-sized droplets are impinging onto a smooth nickel slab heated by induction [1]. Shadow imaging using a high-speed camera allows visualizing the droplet impacts and an innovative drop sizing method combined with Particle Tracking Velocimetry, is implemented for the image processing. Shadow imaging offers benefit of measuring size of droplets of irregular shape while providing directly their spatial distribution. Detection of the object shadow outlines is undertaken using the zero of the laplacian. Then a watershed transform of the particles and the curvature of the object's outlines are examined in order to separate overlapping objects. Tracking of the particles allows adding correlations between droplet sizes and velocities. It results in a Lagrangian description of the flow, particularly valuable for the modeling of the impacts. This algorithm is based on Multi-Hypothesis methods, which are preferred technique in multiple targets tracking systems in cluttered environment [2]. This approach has been adapted to the case of droplet splashing. It allows taking into account events such as appearance of a new droplet, temporary vanishing droplets, droplet coalescence and final disappearance of droplets. A plate dotted with calibrated discs allows evaluating the size measurement accuracy and its sensitivity to the depth of field. Finally, the plate is used to fix a threshold value on the maximum gray-level gradient in order to reject out-of-focus droplets. The low rejection rate in the tracking allows having a limited bias.

Measurements are performed with water and ethanol droplets. The main results concern droplet velocities and sizes before and after the impact and their distributions, as well as the maximum spreading diameter and the residence time in the case of droplet rebounds. Extensive comparisons were performed with models existing in the literature [3-5] and some of them have been extended. Contrary to the available literature, the restitution coefficient (ratio between the velocities after and before the impact) of the velocity component tangential to the wall decreases continuously with the Weber number in both bouncing and splashing regimes. The restitution coefficient for the normal velocity differs significantly from unity even for low values of the Weber number in the bouncing regime. It also decreases with the Weber number before it attains quickly an asymptotic value in the splashing regime. The maximum spreading diameter during the rebound is in agreement with existing models and a new correlation is proposed for the residence time as deviations with the modeling become apparent for Weber numbers greater than 30. In the splashing regime, the Sauter Mean Diameter of secondary droplets appears to be function of a combination of Weber and Reynolds numbers [6].

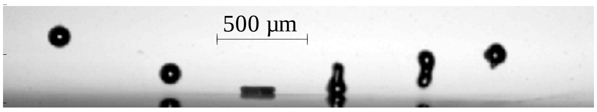

Image of a rebound (f_{inj}=18 200 Hz, D_d=125 µm, We_n=19.26, V=12.37 m/s)

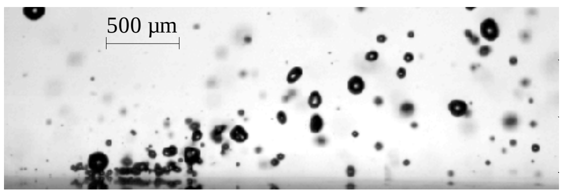

Image of a splashing (f_{inj}=11 000 Hz, D_d=138 µm, We_n=127.55, V=8.9 m/s)

References

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