Droplet Bouncing on Cold Wall: Comparison of Experiments with Direct Numerical Simulations

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Abstract

Bouncing of ethanol droplets on a smooth glass wall have been investigated experimentally and numerically. The results of the experiments and the numerical simulations show very good agreement. The topology of the droplets as well as the air cushion between wall and droplet have been compared. The numerical simulations have been validated by the experiments. Therefore the detailed results of the numerical simulations can be used to obtain a better understanding of the physical processes during the wall impact.

Introduction

The impact of droplets on solid surfaces plays an important role in many natural and technical systems as e.g. raindrops falling on the ground or droplets impinging on the walls of a combustion chamber. In order to understand or to improve these systems a physical understanding of the droplet dynamic processes in detail is necessary. The processes may be studied analytically, experimentally or numerically. The most detailed information is obtained by numerical simulations. However, the Direct Numerical Simulation (DNS) may lasten too long in comparison with calculations using analytical solutions or the problem may be too large for the available computer system. If this is not the case with DNS a comprehensive information about the droplet process is obtained. However, the computer simulations need experimental validation. In this paper we present an experimental validation of numerical simulations of the bouncing process of droplets on smooth dry walls at ambient temperature. The results of numerical simulations, which have already been reported in [1], are directly compared with corresponding experimental results. The results of the comparison give confidence into the numerical simulations.

Materials and Methods

Experiments of the collision of droplets with walls at ambient temperature including bouncing have been reported in [2]. There the experimental techniques for the observation of the wetting behaviour and the topology of the deformed droplets has been described in detail. Collisions with hot walls with temperatures above Leidenfrost temperature are reported in [3]. In addition to the observation of the droplet topology a technique based on frustrated evanescent waves has been developed, which gives qualitative information about the distance of the droplet liquid to the wall. Here, this technique has been applied to the process of bouncing on walls at ambient temperature. Both the observation of the droplet topology and the observation of the distance between the droplet liquid and the wall are a very good basis for the validation of numerical simulations.

For the DNS of the bouncing process the in-house program package FS3D has been used. The numerical setup for this process is described in [1]. More details of the FS3D are given in [4]. The simulations have been performed with periodic boundary conditions in the direction of the movement of the droplets. The length of the computational grid corresponds to the distance of neighbouring droplets of the droplet stream in the experiments in order to obtain realistic conditions.

Results and Discussion

In Fig. 1 the whole bouncing process can be seen, where at the top the monodisperse droplet stream impacting on the wall is shown. At the bottom results of numerical simulations are presented for different times t_i corresponding to the droplets shown in the top picture. A good qualitative agreement can be already found from this figure.

A more detailed comparison is given in Fig. 2. On the left hand side a direct comparison of the topology is shown, which may be used for a quantitative comparison. The experimental results depicted in blue show the reflection on the glass surface. In red the numerical results are indicated. The overlapping of numerical simulations

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and pictures of the experiment are indicated in green. On the right hand side a characterization of the distance between the droplet and the wall is depicted, which is obtained by the method of frustrated evanescent waves. The red line is obtained by numerical simulations, indicating the smallest distance between droplet liquid and wall.

In the full paper a detailed description of the numerical and experimental methods will be given and more comparisons will be shown.

References

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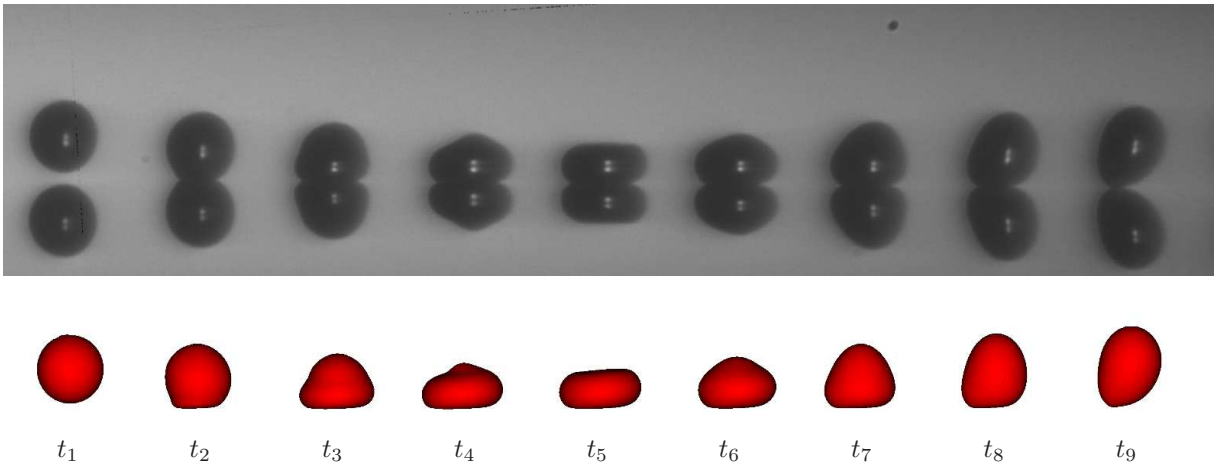

Figure 1. Experimental and numerical results of ethanol droplets with diameter $D = 137\,\mu\mathrm{m}$ bouncing on a smooth surface at ambient temperature. The droplet velocity was $v = 8.9\,\mathrm{m/s}$; the impingement angle between droplet trajektory and wall was $\alpha = 4.3°$ The picture at the top shows a monodisperse droplet stream impinging on a smooth glass surface. Mirror images of the bouncing droplets can be observed. At the bottom corresponding numerical simulations at times t_i corresponding to the droplet of the experiment are depicted.

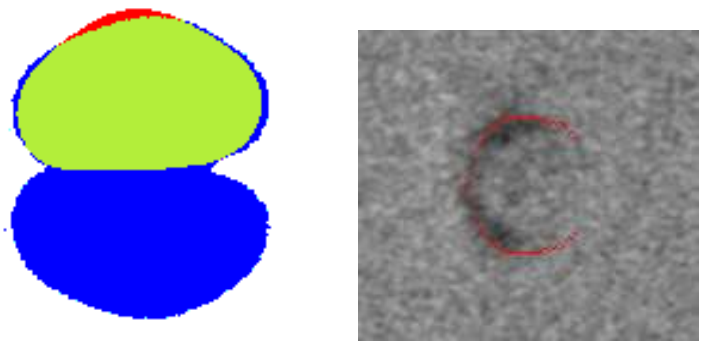

Figure 2. Shown is the situation at $t = t_6$. On the left hand side the direct comparison of topology can be seen. In green the overlapping of experiment and numerical simulation is shown. On the right hand side a characterization of the distance between the droplet liquid and the wall is depicted. The red line is obtained by numerical simulations.