Numerical Study of Binary Droplet Collisions at High Weber Numbers

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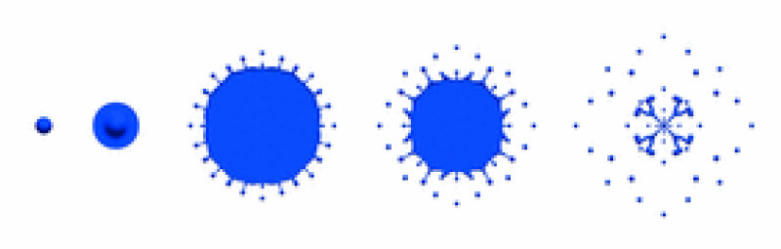


Fig. 1: Simulated evolution of a combined droplet splash resulted from head-on collision of two identical iso-propanol droplets.

Introduction

When two droplets collide with each other, there are some interesting phenomena to be observed: the droplets can bounce off without any material exchanges, the droplets can be permanently combined to a single droplet, and a combined droplet can also be separated into two or more droplets. In case of high Weber numbers, i.e. high collision energy, the collision phenomenon is more fascinating: many secondary droplets are constantly splattered out from the rim of combined droplet at early time after collision. As an example, in technical applications binary droplet collisions influence the droplet size distribution in combustion chamber of an engine and thus the combustor efficiency and the performance of the engine. It is important to understand the dynamics of droplet collisions concerning the scientific interest and technical applications. One important part of the priority programme 1423 of DFG is the numerical investigation of the behaviour of droplet collisions at high Weber numbers.

Methods

In order to conduct the numerical studies, we utilize the in-house code FS3D (Free Surface 3D) which is based on the volume of fluid method (VOF)[1] by which the free surface is implicitly represented by a phase indicator which gives the volume fraction of the disperse phase in a computational cell. To capture the thin lamella of the combined droplet, FS3D is extended with a lamella stabilization method which corrects the calculation of the surface tension force in the lamella region.[2] To reduce computational efforts or to increase the computational resolution, a domain adjustment technique is employed which makes the computational domain suit to the deformation of the combined droplet.

Results

The evolution history of a combined droplet from the numerical

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simulation is shown in Figure 1. The numerical results successfully predict the unstable development of the rim of the collision complex. One observes the extrusion of a fluid-sheet from the middle part of the combined droplet, the undulation of the rim, the formation of finger-like structure and finally the detachment of secondary droplets. In addition, we gained detailed information of the flow inside the combined droplet taking advantage of the fully resolved numerical simulations.

Discussion

Based on the current numerical results we are aiming to gain more insight into the unstable phenomena at the developing rim of the combined droplet. Simulations with different collision conditions as well as with different droplet materials will make it possible to study the characteristics of the unstable rim. Our principal aim is to find the answer to the question what mechanisms lead to the fascinating phenomenon of splashing!
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Reference

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2. C. Focke and D. Bothe (2011), Computational analysis of binary collision of shear-thinning droplets, J. Non-Newtonian Fluid Mech. 166: 799-810. https://doi.org/10.1016/j.jnnfm.2011.03.011

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