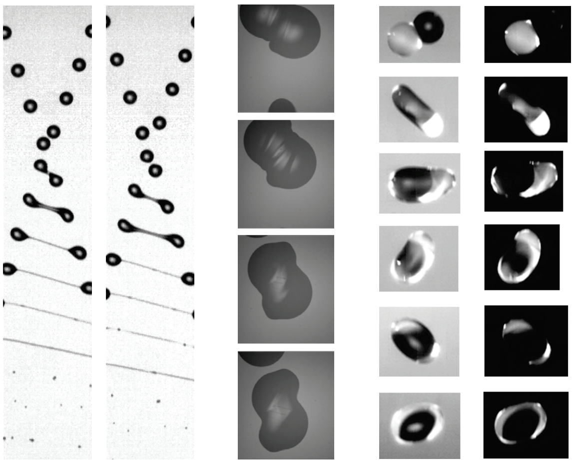
Multi-scale experimental analysis of binary droplet collisions

Martin Sommerfeld and Lars Pasternak
Multi-Phase Flow Working Group
Faculty of Process- and Systems-Technology
Otto-von-Guericke University (OvGU)
Zeppelinstraße 1, D-06130 Halle (Saale), Germany
E-mail: martin.sommerfeld@ovgu.de

Abstract

Binary collisions of liquid droplets in a gaseous environment have been analysed experimentally for several decades, mainly aiming at deriving appropriate collision maps characterising the outcome of a the collision processs in termas of the non-dimensional impact parameter (i.e. lateral displacement of droplets centres upon contact) and the Weber-number (i.e. determined by the relative velocity and the diameter of the smaller droplet). This information is essential in modelling droplet collisions in the frame of a Euler/Lagrange calculation as commonly used for spraying systems in many engineering fields. Unfortunately such collision maps depend on a number of other parameters not involved in the two parameters impact parameter and Weber-number. These are mainly size ratio, viscosity ratio and properties of the gaseous environment. Therefore, a development of more generalised models (Sommerfeld 2016) including theoretically derived boundary lines require further detailed experiments for a range of liquid properties.

The present experimental studies were done using two vibrating orifice droplet generators (droplet size between 300 and 800 μm) and a backlight illumination combined with two high-speed cameras (Kuschel & Sommerfeld 2013; Sommerfeld & Kuschel 2016). Measurements for visualising the entire collision process were done with a lense yielding a resolution on 25 μm/pixel, in order to determine the collision outcome and to obtain the number and size of possible satellite droplets. The emphasis in these studies was the modification of the collision maps for a range of liquid viscosities between 1 mPa·s and 60 mPa·s (Figure 1 a) and different droplet size ratio, however concentrating first on identical viscosity. High resolution imaging was performed using between 2 and 5 μm/pixel. In these studies, details of the collision process were resolved, such as the occurrence of air cushions between the interacting liquids (Figure 1 b). Moreover, the collision behaviour of droplets with different viscous liquids was of interest (Figure 1c), a situation found in many applications. For this purpose, backlightning and a laser light sheet were used and one liquid was doped with fluorescent dye.



a) b) c)

Figure 1: Analysis of binary droplet collisions at different scales: a) separation at higher viscosity, FVA1 oil droplets with: t = 23°, μ = 28.2 mPa·s; b) high resolution imaging of droplet collision with air enclosures (μ = 6 mPa·s); c) encapsulation of a higher viscous droplet by a low viscosity droplet, We = 40.6, B = 0.32, $\eta_h / \eta_l = 60/ 2.6 = 23$.

Keywords

Binary droplet collisions, liquid properties, droplet size ratio, bouncing, coalescence, stretching, high-speed shadow imaging, multi-scale analysis, modelling collision outcomes.

References

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