Experiments and Direct Numerical Simulations of binary collisions of miscible liquid droplets with different viscosities

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Abstract

Binary droplet collisions are of importance in a variety of practical applications comprising dispersed two-phase flows. The background of our research is the prediction of properties of particulate products formed in spray processes. To gain a more thorough understanding of the elementary sub-processes inside a spray, experiments and direct numerical simulations of binary droplet collisions are used. The aim of these investigations is to develop semi-analytical descriptions for the outcome of droplet collisions. Such collision models can then be employed as closure terms for scale-reduced simulations.

In the present work we focus on the collision of droplets of different liquids. During spray drying the residence time of droplets will vary and their viscosity will be increased as a result of the drying process. In recirculation zones droplets of different drying state (i.e. different solids content and viscosity) may collide with each other. Due to the evaporation of the solvent, collisions of unlike viscous droplets will mostly exhibit also a diameter ratio less than unity.

In order to investigate these collisions, the experimental method as well as the numerical code are extended to analyze the collision of different liquids. A new experimental method has been developed in order to visualize the mixing and penetration process of two colliding droplets. Therefore, the fluorescence marker Rhodamine B is added to one liquid and droplets are excited by an Ar+ Laser. A combination of LED back light and fluorescence light is recorded with two synchronous cameras, whereas the second camera only records the fluorescence in order to have more details on the distribution of the fluorescence marker. Thus it is possible to study not only the dynamical behavior of the collision complex (outer surface) but also the internal mixing and even penetration can be analyzed quantitatively. Another advantage which comes with the new method is based on the fact that numerical researchers now have better validation data due to the high time resolution.

In the numerical part of the work we investigate the collision of droplets of different liquids and assume that surface tension and density are equal. The liquids are miscible, so no surface tension is acting at the liquid-liquid interface. The numerical method is extended to simulate the collision of different viscous droplets by solving an additional transport equation to simulate the mass fraction distribution inside the collision complex. The viscosity is coupled to the mass fraction and a careful averaging is employed at the liquid-liquid interface to capture the dynamics of the interface. The experimental data is used to validate the effect of non-constant viscosity. Subsequently, the local field data is used to gain a deep insight into the flow within the colliding droplets.

This study is devoted to the investigation of such collisions experimentally as well as numerically in order to analyze the effects of penetration and mixing. One primary is to discover elementary phenomena caused by the viscosity ratio of the droplets.

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