Experimental investigation of droplet collisions with higher viscosity

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Abstract

The present work focuses on the investigation of binary droplet collisions consisting of solutions with different mass fraction of solids. The increase of solids content is associated with a remarkable increase in viscosity. In order to generate mono-disperse droplets two fine liquid jets are excited by means of piezo-electric generators causing a controlled break-up. The impact parameter and the relative velocity included in the We-number are changed systematically. The methodical part will concentrate on a different method to describe the tracking of the droplets to determine the relative velocity and the resulting trajectory of the colliding droplets. Mass fraction and hence viscosity have a great influence on the collision outcome and cause a shift of the impact parameter–Weber number–diagram (B–We–diagram) towards higher Weber numbers [3].

Introduction

During the last decades many experiments on droplet collisions were carried out with different types of liquids [1, 2, 3, 4, 5, 6, 7]. Nearly all of them had in common, that they used roughly the same range of rather low viscosity (i.e. 1-5 mPa s) for their experiments. Jiang et al.[6] recognized that alkanes with different viscosities caused a shift of the boundary curves between the different collision outcomes towards higher We-numbers. Kurt [6] was one of the first who studied the influence of solid particles in suspensions on the collision behaviour. We want to step back slightly by analysing the influence of the solids content in solutions.

This work aims at investigating a wider range of viscosity for different polymerized Polyvinylpyrolindones-PVP (1-Ethenyl-2-pyrrolidone) with respect to the collision outcome.

Materials and Methods

Experimental Work

The experiments were carried out by using two piezo-electric droplet generators (see fig 1). The angle between the droplet chains and the pressure were varied in order to change the relative velocity in a range of 0.5 to 3.5 m/s. The liquid was pressed through the nozzle (producer: encap biosystems) with a diameter of 200 µm, resulting in droplets of around 380 µm in size. The temperature was kept constant at about 22°C by a thermostat. The Impact parameter was modified by using the *aliasing* method (frequency shift) [4]. Two CCD-cameras were used, observing the collision under an angle of 90° (front view or collision plane and side view).

Tracking of droplets

In the experiment the droplets fly, if the jet is excited properly, on a straight path, which can be described by a linear regression of the centres of gravity of the droplets. In practice however, the velocity vectors measured via image analysis are slightly fluctuating. This implies that the collision point also fluctuates, with the result that the impact parameter for a given geometry of the collision event will vary.

If one assumes the linear regression as the real trajectory or direction of flight one can derive the real impact parameter by calculating the normalized regression vector multiplied with the measured velocity vector. This yields the velocity of the droplet in direction of the trajectory (fig. 2).

Results and Discussion

In figures 3 and 4 the comparison between the droplet motion simulated by the tracking method mentioned above and the experiment is shown. The pictures fig. 3 a) and b) were used to determine the velocities and the regression vector. Pictures 3 c) and d) show the impact of the marked droplets from figure 3 a). Figures 4 c) and d) illustrate the simulated droplet motion. The new tracking method shows very good agreement with the experiment and proves that the impact parameter is also correctly calculated for drops which are more far away from the actual collision point. The marked droplets of picture 3 a) are also depicted in Figure 4 a) to show the droplets belonging together more clearly.

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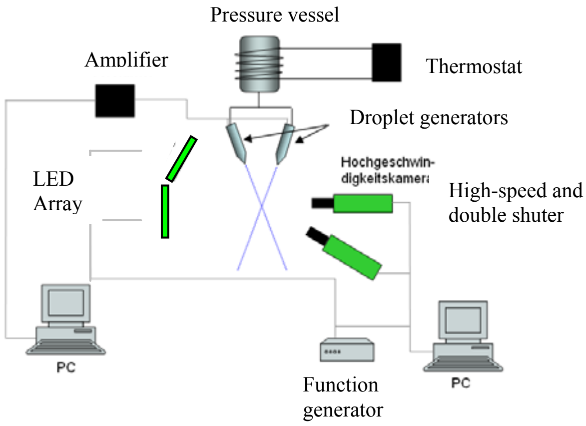

Figure 1. Sketch of the experimental setup

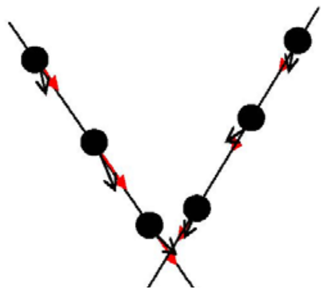

Figure 2. Sketch of the correction of the velocity vector in direction of the averaged direction of flight; not filled arrows: measured velocity vector; filled arrows: corrected direction of flight

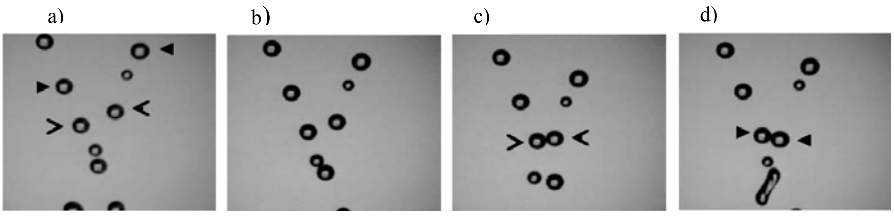

Figure 3. Pictures a) and b) were used to determine the velocity of the droplets; droplets marked with arrow heads of same shape will collide with each other; c) and d) show the impact of the droplets from the first picture.

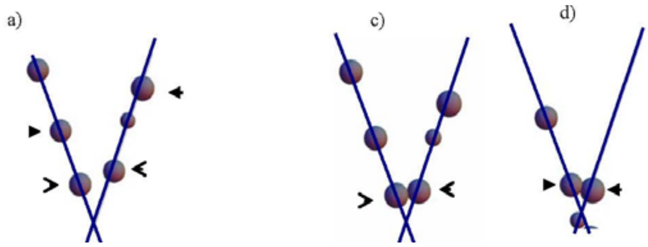

Figure 4. Simulated droplet impacts using the new tracking method.