Experiments on Bubble Breakup Induced by Collision with Vortex Ring.

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Breakup of bubbles in a turbulent flow is a phenomenon widely encountered in many industrial applications (boiling, waste-water treatment, heat and mass transfer intensification, etc.). For numerical simulations of these complex processes, the knowledge of two parameters characterising the bubble breakup is essential: i) breakup frequency and ii) size distribution of daughter bubbles after the breakup. There exist many theoretical models predicting these two parameters (reviewed e.g. by Liao & Lucas 2009). Most of them are based on the concept where a bubble encounters a turbulent eddy and the breakup parameters result from balance of eddy energy and surface tension (surface energy) of the bubble. In spite of waste body of literature dealing with the bubble breakup (Solsvik et al. 2013, Vejrazka et al. 2018), only limited amount of experimental data are suitable for validation of theoretical models. The aim of present work is to provide an experiment, in which a single bubble collides with a single eddy. Such simulation of bubble-eddy collision provides experimental data suitable for validation of theoretical models.

The experiment is based on the production of a bubble and a vortex ring moving against each other until they collide (Figure 1). Vortex ring is generated by pulse-flow from an immersed nozzle (1.2 and 0.7 mm in diameter, duration of pulse-flow is typically 25 ms). Bubble of defined size (ranging from 0.9 to 1.9 mm in diameter) is produced by bubble generator based on movable capillary (Vejrazka et al. 2008).

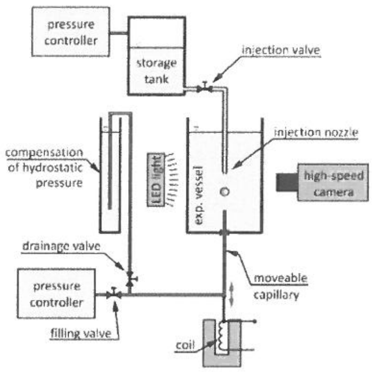

Figure 1: Experimental setup

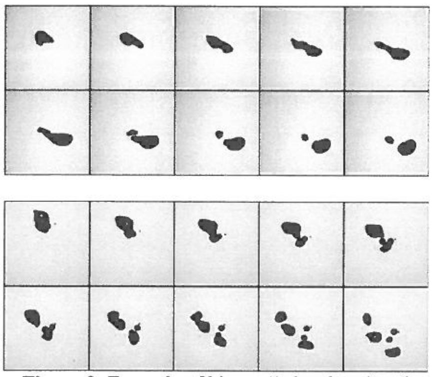

Figure 2: Example of binary (2 daughters) and multiple (5 daughters) bubble breakup

The collision process is observed by a high-speed camera in order to track the mother bubble as well as daughter bubbles arising from the breakup. Breakup probability, number and size distribution of daughter particles are determined in dependence on mother bubble size and intensity of vortex ring. The intensity of vortex ring is assumed as the circulation of velocity field introduced by pulse-flow from the nozzle. The circulation is estimated using two ways: i) from total amount of liquid injected by a nozzle and velocity of propagating vortex ring obtained from high-speed video and ii) using numerical simulation of vortex ring formation.

When a bubble encounters a vortex ring, the bubble deforms and either breaks into smaller daughters (Figure 2) or drifts away without breakup. The breakup probability depends on bubble size and intensity of the vortex ring. Under low vortex intensity, only binary breakups are observed with similar probability to obtain two equal-size bubbles or one small and one large bubble (uniform daughter size distribution). Increasing the vortex intensity, both binary and multiple breakups occur. Smaller bubbles provide binary breakup with U-shaped daughter size distribution, where bubble breaks more probably into one small and one large bubble. Larger bubbles break with high probability into several daughter bubbles (multiple breakup) with uneven bubble size distribution.

Present experimental setup allows to produce reproducibly both bubbles of defined size and vortex rings with given intensity. Thus, we can simulate the bubble-eddy collision and quantitatively study the dynamics of breakup process. Obtained experimental data are then suitable to test theoretical models for breakup of fluid particle.

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