Experimental and numerical investigations of drop size distributions in stirred liquid/liquid systems

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Abstract

The dispersion of an immiscible fluid in a turbulent liquid flow is commonly found in many technical as well as natural processes, with major importance for chemical, pharmaceutical, mining, petroleum, and food industry. The drop size distribution resulting from the opposed phenomena of turbulent drop breakage and coalescence plays an essential role in the overall performance of these processes. The population balance equation can be used to describe and predict drop size distributions in turbulent flows, i.e. stirred liquid/liquid tanks. A lot of different - sometimes even contradictory - model approaches for the breakage term, including the breakage rate, the number and distribution of the daughter drops, and the coalescence term have been published in the last decade. Nevertheless, the prediction of drop size distributions as a function of power input, material and process parameters is still inaccurate and the submodels applied in the population balance equations need further improvement. To get a deeper insight into the breakage phenomena and describe it mathematically more accurate, experimental and numerical investigations concerning location and mechanism of drop breakage are conducted in this work.

In stirred liquid/liquid tanks coalescence and breakage occur simultaneously. For more detailed understanding and a physical description of the phenomena, the consideration of each single process is needed. To investigate the breakage process different approaches including the use of surfactants or low disperse phase fractions exist. In this work a special set up was built up for the investigations of the drop breakage event. A single blade representative for a section of a Rushton turbine is fixed in a rectangular channel. A single droplet is introduced in a continuous flow and the break up at the stirrer blade is determined with a high speed camera (see figure1).

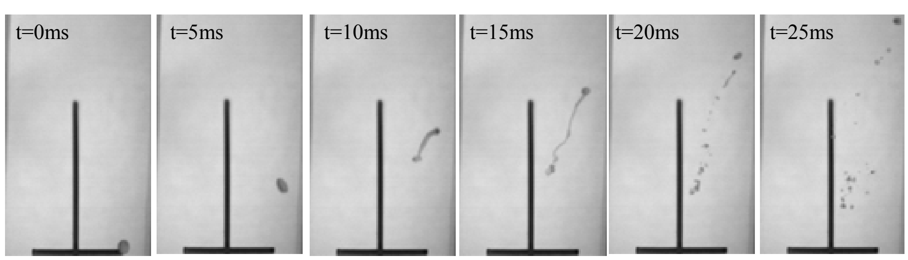

Figure 1: Drop breakage of a 2 mm mother droplet

An automated image analysis delivers results for the breakage time, number and distribution of daughter drops and the location of the break up event. The influence of the mother drop diameter (300-5000 µm) and the velocity of the liquid flow (1-3 m/s) on the breakage event will be

presented. Additionally the influence of different disperse phases (toluene/petroleum) and the impact of the continuous phase properties (i.e. pH-value) will be displayed.
To determine the breakage mechanism the experimental results will be correlated with computational fluid dynamics (CFD) results of the continuous fluid flow. The numerical simulations of the flow in the channel are performed with the in-house flow solver FASTEST-3D, which is based on a fully conservative finite volume method for the solution of the incompressible Navier-Stokes equations on a non-staggered, cell-centered, blockstructured, boundary-fitted grid. Due to the turbulent conditions of the channel flow, the Reynolds averaged Navier-Stokes (RANS) equations and the Large Eddy Simulation (LES) are used.
The aim is the calculation of the flow properties, the prediction of the turbulent structures behind the blade and the identification of the regions with the highest energy dissipation and shear rates.
By comparing these results with the experimental ones, mathematical correlations between the location of the drop breakage events and the flow properties will be shown.
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keywords: stirred tank, liquid/liquid systems, drop breakage, breakage rate, population balance equation, computational fluid dynamics, single drop breakage

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