Detailed Drop-Based Simulation of Settling Behavior.

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Abstract. Iso-optical systems were used to experimentally characterize the settling behavior of two liquid phase with high spatial and temporal resolution. These results were compared with drop-based detailed simulations. The comparison showed that lag time at the beginning of settling can be explained by very small initial drop size. The results also showed that a close-packed dispersion, where drops are in direct continuous contact, is hardly occurring.

Keywords: phase separation, settling, drop-based modelling, coalescence model, sedimentation model, close-packed dispersion

Objectives

After solvent extraction steps in biotechnology, hydrometallurgy including urban mining, etc., the separation of the two liquid phases is often a major challenge. Impurities and minor components can strongly influence the settling behavior. Therefore, a tool is sought to provide a reliable description of the settling process as basis for process and equipment design. Here, a drop-based approach is adopted, where individual drops are tracked as they pass through the settler. To validate the applied models, it is not sufficient to consider only the sedimentation and coalescence curves. Rather, a detailed data set on local holdup as a function of time and position is required. Such data can be obtained with iso-optical systems, where the interfaces become invisible and thus the local phase ratio can be determined from the color intensity when one of the phases is colored with a dye.

New Results

Settling experiments were performed in a standardized settling cell using the iso-optical system water + hexane + ethylene glycol, with methylene blue added to color the aqueous phase. The videos of the experiment were quantitatively evaluated based on the Lambert-Beer law to determine the local hold-up of the dispersed phase (see Figure 1). The initial drop-size distribution was determined using a SOPAT probe with slightly non-iso-optical systems, ensuring that these slight concentration shifts did not alter the drop-size distribution by varying the concentration in two directions.

In parallel, a simulation tool was developed that allows a drop-based simulation of the settling process. The individual drop effects are considered, such as drop sedimentation in a polydisperse drop swarm, drop-drop coalescence during sedimentation and in the densely packed zone, and drop-interface coalescence. This detailed modeling along with experimental validation provided new insights into the fundamentals of phase separation.

During settling in technical systems, a lag time is often observed during which essentially no sedimentation is observed. It was shown that this is due to the initially very small drops that are encountered. Only when the droplet size reaches a certain size around 200 μm due to

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drop-drop coalescence, does the sedimentation velocity become large enough for sedimentation to be observed visually. This also leads to the observation that the typical drop size determined from sedimentation experiments for a given material system is independent of the details of dispersion generation.

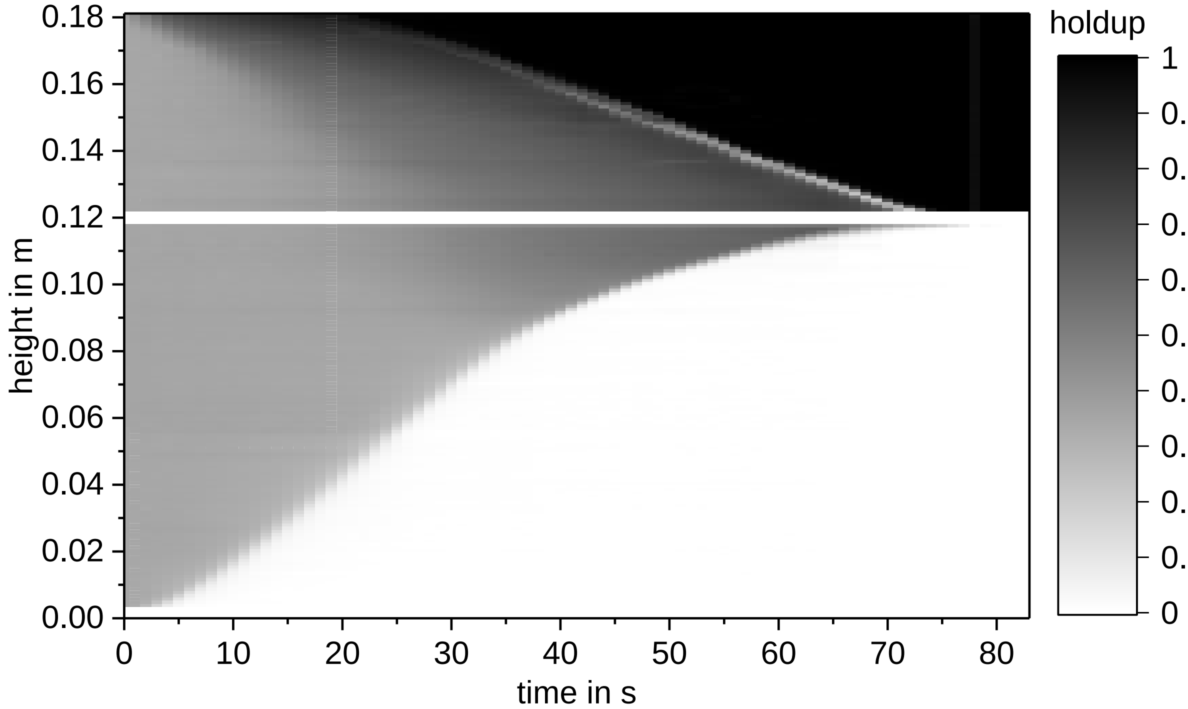

Figure 1: Result of the evaluation of an iso-optical settling experiment.

Previously, it was assumed that a zone of high hold-up in the settling experiments corresponds to a so-called close-packed zone, where the drops are in direct contact with several drops simultaneously. In that zone, sedimentation hardly occurs. Based on the hold-up data as well as in the simulations, it could be shown that a zone exists in which droplets sediment freely at high hold-up. The local holdup hardly at all reaches values that exceed the close-packing limit. This has a significant influence on the settler simulation. In this zone, the coalescence of two randomly colliding droplets must be considered, not the coalescence in a zone of closely stacked droplets, which transfer the hydrostatic pressure over the entire close-packed zone.

Conclusions

Detailed modeling and validation with standardized settling tests based on iso-optical systems provided new insights that change the interpretation of settling experiments and that changes, which effects must be considered in drop-based settler design.