Ph.D. Seminar

Liquid-Liquid Phase Separation in Gravity Settlers: Measurements, Population Balance Modeling and CFD Simulations

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Abstract

Separation of liquid-liquid dispersion is an integral part of a variety of process; for example, crude oil processing (crude desalting), hydrometallurgy (solvent extraction), etc. Mixer–settlers are widely used in the solvent extraction because of their advantages over the other equipment. In a mixer–settler, two immiscible liquid phases enter the mixer, and the organic phase is dispersed into the aqueous phase in the mixer (used for extraction) and then the dispersion flows into a large–sized gravity settler. The dispersion undergoes binary and interfacial coalescence that occur within the dispersion band inside the settler and results into phase separation. While there exist many reports available on mixer operations, a limited information reported in the literature on the separation phenomena in gravity settlers. The separation performance inside the settler depends on operating parameters (e.g., dispersion flow rate, dispersed phase volume fraction and drop size), geometrical parameters (e.g., settling area and dispersion inlet position) and rates of interfacial and binary coalescence. Therefore, understanding of the effects of aforementioned parameters in the phase disengagement is very important to improve the separation performance of settlers, which in turn can help in optimization and design of settlers. Further, for the design and scale-up of gravity settlers, it is important to develop the CFD models that account for the binary and interfacial coalescence processes.

In the present work, experimental investigations of liquid–liquid disengagement are performed in a laboratory–scale continuous gravity settler. The effects of different operating and geometrical parameters on the phase disengagement are investigated. Based on the measurements and the data reported in the literature, an empirical correlation is proposed to predict the dispersion–band height. Further, to develop an understanding on the drop coalescence process, the micro-scale experiments are performed to measure the frequency of interfacial and binary coalescence in presence of single isolated drops and multiple drops. These measurements provide crucial database required to develop kernels for the interfacial and binary coalescence rates. Such kernels are important to predict the drop size distribution using the population balance (PBM) or integrated CFD+PBM models.

Further, the Eulerian multi-phase model is developed in the open source CFD code OpenFOAM to simulate the gravity separation process. In addition, a stand-alone PBM is developed and integrated with the multi-phase CFD model to predict the drop size distribution and dispersed phase volume fraction within the dispersion band. Moreover, since the interfacial coalescence govern the separation process in the settler, the interfacial coalescence module is incorporated in the CFD model (CFD+PBM+IC). Initially, the developed CFD+PBM+IC model is used to simulate the separation process in a batch settler to build the confidence on the predictive capabilities in the relatively simple system (due to the absence of convective flow in comparison to the continuous gravity settler). To validate the developed model, the batch settling experiments are performed in a laboratory-scale batch settler. Later, the CFD+PBM+IC solver is used to perform the simulations of liquid-liquid disengagement in the continuous-gravity settler to predict the dispersion band height, drop size and dispersed phase volume fraction distribution within the dispersion band and predictions are validated with measurements. The computational model developed in this work will be useful to predict the separation process in gravity settlers and to optimize their separation performance.