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Experimental Investigations of Interfacial and Binary Coalescence of Multi-layered Drops

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Highlights

- Coalescence of drops in multiple layers measured using high-speed imaging.
- Estimation of interfacial and binary coalescence rates.
- Effects of physical properties, drop size distribution and flow field on binary and interfacial coalescence rates.

1. Introduction

Separation of liquid-liquid dispersions is important to many process applications, such as liquid-liquid extraction and reactions, hydrometallurgical applications, crude desalting, etc. While several different process equipment are used for liquid-liquid separations, continuous gravity settlers are commonly used in hydrometallurgical processes. The performance of coalescers or gravity settlers is controlled by the rates of interfacial and binary coalescence. While there exists many reports on the interfacial coalescence of single drops and binary coalescence of two drops, a very few reports are available on binary and interfacial coalescence in presence of multiple drops and on effect of multiple drop layers (as present in dispersion bands formed in industrial settlers) on coalescence rates. In addition to presence of multi-layered drops, convective flow within the dispersion band further influences binary and interfacial coalescence processes. Therefore, it is important to study the interfacial and binary coalescence in presence of multi-layered drops in the stagnant and flowing liquids. The main objective of the present work is to analyze interfacial and binary coalescence in presence of multiple drops and to quantify the effects of drop size, interfacial tension, and viscosity of the liquids on interfacial and binary coalescence rates in quiescent and flowing systems using high-speed imaging.

2. Methods

In the present study, coalescence experiments were performed in a small vertical channel made of PMMA (see Figure 1). The channel was filled with demineralized water and kerosene was injected using a syringe pump through different needles provided at the bottom of the channel (see Figure 1). Needles of different diameters were used to generate mono-dispersed drops in the size range of 0.5 to 4 mm. A high-speed camera was used to record interfacial and binary coalescence process near the oil-water interface. Further, the effects of different physical properties on the rate of interfacial and binary coalescence were investigated. For this purpose, water and oil soluble surfactants (SDS and SPAN-80) were used and rate of coalescence was measured. The detailed information on the experimental set-up, interfacial and binary coalescence measurements performed for different velocity fields and effects of drop size distribution, viscosity of water and interfacial tension on the coalescence process will be presented at the conference.

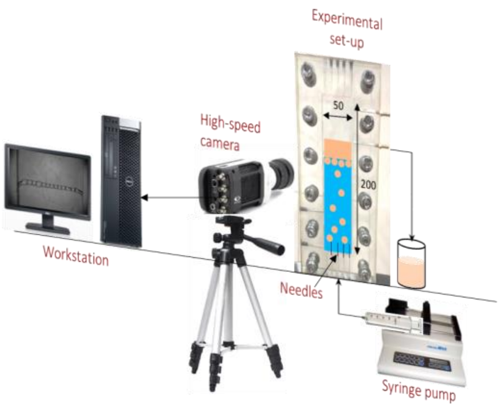

Figure 1. Schematic of experimental set-up (all dimensions are in mm)

3. Results and discussion

In the present work, coalescence rate (K_c) was measured at the interface for different dispersion band heights (H_{db}). H_{db} was maintained by controlling incoming drop number density i.e. by controlling the kerosene flow rate. Initially, rate of coalescence for single isolated drop was measured and later experiments were performed to measure the rates of coalescence for different dispersion band heights. Typical pictures of

the dispersion bands considered for measurements are shown in Figure 2(a). With increase in number of drops (or drop layers), due to buoyancy force exerted by the drops in the lower layers on the drops near the liquid-liquid interface, drainage time of liquid film between drops present near the interface was decreased. As a result, the rate of interfacial coalescence was increased with dispersion band height (see Figure 2(b)). Further, due to increased number of incoming drops, position of drops was changed continuously within the dispersion band. Therefore, interaction time of a drop with its neighbouring drops was not sufficient for binary coalescence and this led to a lower rate of binary coalescence in comparison to the interfacial coalescence rate.

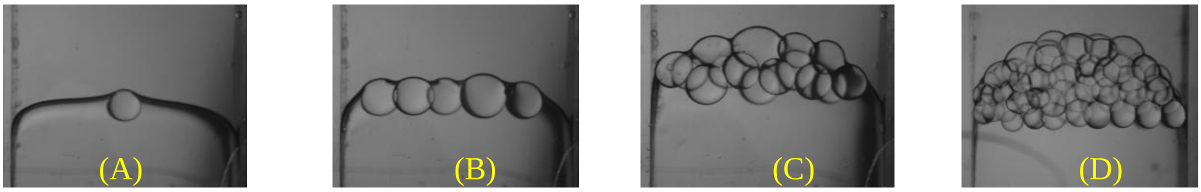

Figure 2(a). Snapshots of drop layers

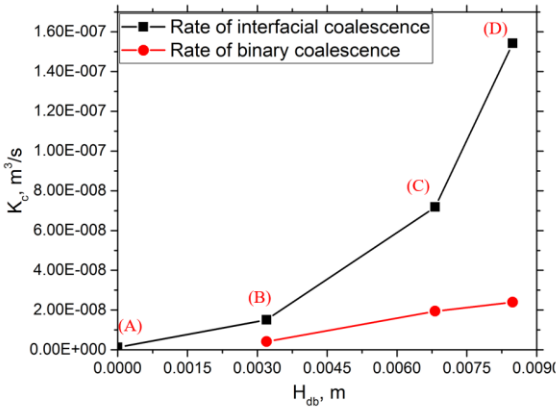

Figure 2(b). Rate of interfacial and binary coalescence at different dispersion band height (the corresponding images A, B, C & D are shown in Figure 2(a))

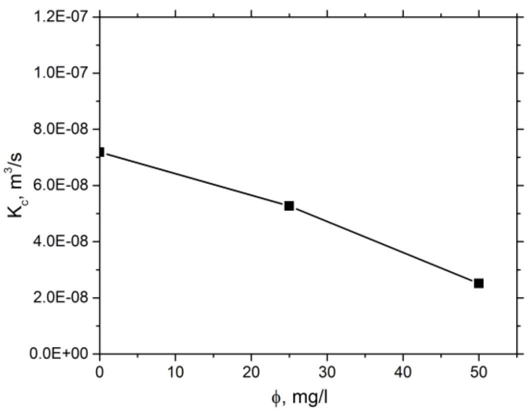

Figure 3. Rate of interfacial coalescence at different concentration of surfactant (ϕ)

In order to investigate the effect of interfacial tension, experiments were performed by adding the SPAN-80 non-ionic surfactant in the oil phase. The rate of coalescence was decreased with increase in surfactant concentration (see Figure 3). Due to the presence of a surfactant, the drops became more stable. Therefore, the time required for the film drainage was increased and this led to a lower interfacial coalescence rate. The results on effects of drop size (0.5 - 4 mm) and viscosity of continuous phase ($7.97 \times 10^{-4} – 6.04 \times 10^{-3}$ kg/ms) on interfacial and binary coalescence rates will be presented at the conference. In the industrial settlers e.g. continuous gravity settler, dispersion is continuously fed to the settler and this leads to a convective flow in the settler. In order to understand the effects of such convective flow on rates of interfacial and binary coalescence, experiments will be performed to measure the coalescence rate in simple shear and pulsing flow conditions.

4. Conclusions

In the present work, we have performed high-speed imaging experiments to measure the rate of interfacial and binary coalescence arising due to buoyancy force. The effect of presence of multiple drops on the coalescence rates was investigated by performing experiments with varying heights of dispersion band. The effect of physical properties (interfacial tension and viscosity) on the coalescence rates was investigated. Further experiments will be performed to measure the coalescence rate in simple shear and pulsing flow conditions. These measurements will be useful to develop kernels for interfacial and binary coalescence rates. The predictive abilities of population balance models (PBM) or integrated CFD+PBM models are strongly dependent on the kernels used to estimate the coalescence rates. The present work will help to develop improved kernels for interfacial coalescence and buoyancy driven binary coalescence in flowing systems.

Keywords: Binary and interfacial coalescence, multiple drops, high-speed imaging, drop size distribution.