Drop coalescence with liquid-liquid interface in the presence of surfactants

T.Dong, W.H. Weheliye, and P. Angeli

ThAMes Multiphase, Department of Chemical Engineering, University College London, Torrington Place, WC1E 7JE, UK; p.angeli@ucl.ac.uk

In this work, the effects of surfactants on the coalescence of single drops with liquid-liquid interfaces are investigated. For the studies, high speed imaging, particle image velocimetry and laser induced fluorescence techniques have been used to study the evolution of the interfaces and the velocity fields in the drops. At first, the coalescence of drops with stationary interfaces in two dimensional (Hele-Shaw) and three dimensional cells will be discussed. In the 2D configuration it was found that immediately after the film rupture, the neck growth follows a linear trend for all surfactant concentrations. By assuming interfacial tension values corresponding to twice the surfactant concentration in the bulk, the expanding neck velocities for all surfactant concentrations studied collapse to the same scaling law. The distribution of surfactants on the interfaces during coalescence was further probed with planar laser-induced fluorescence. The two liquid phases had, in this case, matching refractive indices and a fluorescently tagged surfactant was added in the aqueous phase. It was found that during the film thinning, the surfactant molecules were swept outwards by the draining liquid while after the film rupture, the concentration of the surfactants at the tip of the meniscus is indeed high and above its equilibrium value.

Surfactants were found to reduce the partial coalescence region in an Oh-Bo phase map. In the gravity regime of the map, surfactants had a negligible effect on the daughter to mother drop diameter ratio while in the inertia-capillary and in the viscous regimes, an increase in the surfactant concentration resulted in lower drop diameter ratio. Surfactants reduce the interfacial tension while they make the coalescence non-symmetrical, which prevents partial coalescence.

Coalescence was found to be delayed by moving liquid interfaces. A novel flow channel was fabricated that enabled different interface speeds to be studied. It was found that as the interface speed increased the delay in coalescence also increased. This is attributed to the lubrication pressure which develops in the draining film. In addition, with moving interfaces most of the film rupture points appear on the downstream part of the drops.

ACKNOWLEDGEMENTS

This project was funded under the UK Engineering and Physical Sciences Research Council (EPSRC) Programme Grant MEMPHIS. Teng Dong would like to thank the UCL-CSC scholarship for providing his studentship.

REFERENCES

1. Chinaud, Maxime, Victor Voulgaropoulos, and Panagiota Angeli. Surfactant effects on the coalescence of a drop in a Hele-Shaw cell. Physical Review E 94.3 (2016): 033101.

2. Dong, Teng, et al. An experimental study on the drop/interface partial coalescence with surfactants. Physics of Fluids 29.10 (2017): 102101.

3. Dong, Teng, Weheliye Hashi Weheliye, and Panagiota Angeli. Laser induced fluorescence studies on the distribution of surfactants during drop/interface coalescence. Physics of Fluids 31.1 (2019): 012106.