Controlled Collision of Hele-Shaw Droplets in Extensional Flow Using a Six-Port Microfluidic Device

Aysan Razzaghi[1] and Arun Ramachandran[1]

[1]University of Toronto, Ontario, Canada

ABSTRACT

Collision of two dispersed droplets in the matrix of suspending liquid is the first step toward coalescence. However, to quantify the rate of coalescence, the configuration of the collision should be definable and the force that induces the collision should be measurable. We present a strategy to use the hydrodynamic force in a six-port microfluidic channel to steer two channel-spanning (Hele-Shaw) droplets towards collision.

The analytical solution of the flow field that accounts for the perturbation of the flow due to the hydrodynamic interactions between the Hele-Shaw droplets was developed using the conformal mapping technique. By implementing the analytical solution in the control loop, the flow rates that are required to steer the droplets toward their respective target points can be determined, using a single control parameter, χ^*. The parameter χ^*, is in fact a characteristic time scale that can manipulate the droplets in one of the two manners: 1) by engaging all six ports to create a flow field with two stagnation points ($\chi^* \ll 1$), or 2) by deactivating some of the ports and creating a linear extensional flow through the remaining active ports ($\chi^* \gg 1$). We further determine specific orientations that are more suitable for the collision of Hele-Shaw droplets in the six-port microfluidic channel.

Based on the strategy above, we design and perform controlled head-on and glancing collisions for ~100 μm radius Hele-Shaw perfluorodecalin droplets in silicone oil. The range of the capillary number (ratio of the viscous to interfacial force) that is considered varies from 10^{-3} to 10^{-1}. Coalescence time between two Hele-Shaw droplets undergoing a head-on collision in a dimpled mode was found to be independent of the strain rate of the hydrodynamic flow.

ACKNOWLEDGEMENTS

We acknowledge the funding support from Syncrude Canada Ltd and NSERC Collaborative and Research Development Grant CRDPJ 514675-17.