Using MRI Techniques to Study Coalescence of Emulsions

Vannarith M. Leang[1], Robert L. Powell[1], Ronald J. Phillips[1], Stephanie R. Dungan[2], and Jeffrey Walton[3]
(1)Chemical Engineering and Material Science, University of California-Davis, Davis, CA 95616
(2)Food Science and Technology, University of California-Davis, Davis, CA 95616
(3)NMR Facility, University of California-Davis, Davis, CA 95616

An emulsion is a thermodynamically unstable mixture of two immiscible fluids with one fluid being dispersed in the other. Coalescence, which is the fusion of two similarly sized drops forming a larger drop, is one of several emulsion breakdown methods. The coalescence mechanism can be broken into four distinct steps: Collision, Film Drainage, Film Rupture, and Confluence. These four steps happen sequentially, each step with its own time scale. Our research focuses on the first two steps, collision and film drainage, which are dominated by hydrodynamic forces. We are able to study hydrodynamic forces in the coalescence process by shearing the emulsion.

We use Magnetic Resonance Imaging (MRI) techniques to detect when shear induced coalescence occurs. MRI is a noninvasive and insensitive technique that allows us to detect changes in the emulsion as coalescence occurs. We are able to measure flow fields, drop-size distinctions, and concentration profiles using MRI. The flow field is detected using a Time-of-Flight pulse sequence where a saturation pulse is applied to give a one-dimensional profile. The drop size distribution is detected using a Stimulated Echo pulse sequence with two applied magnetic field gradients. The two field gradients will allows us to detect displacement of molecules diffusing, which will give us a drop size distribution through the use of Restricted Diffusion Theory.

In studying hydrodynamic forces in the coalescence mechanisms, we have identified a few parameters that will likely play an important role in the rate of coalescence. We have chosen to vary the shear rate, oil volume fraction, initial size distribution, and viscosity of the emulsion system. MRI results confirm that an increase in volume fraction and drop size increases the rate of coalescence while increasing the viscosity decreases the rate of coalescence.

Furthermore, our results have shown that for a polydispersed emulsion, coalescence will likely happen with bigger drops than with smaller drops. Also, coalescence does not occur homogeneously throughout the emulsion, but rather only an initial small fraction of the emulsion undergo coalescence. As coalescence progresses, the small volume fraction becomes larger and creams out of the emulsion as bulk oil, which in turn affects the imposed flow field. The flow field starts out unidirectional before turning complex as the macroscopic oil drops cream out of the emulsion. These results will help us develop a system where coalescence is likely to occur homogeneously so that MRI will be able to detect an increase in the drop size distribution. This in turn will enable us to characterize which parameters are most important in the coalescence mechanism.