The Impact of Surfactant Type on Hydrate Formation in Flowing Systems

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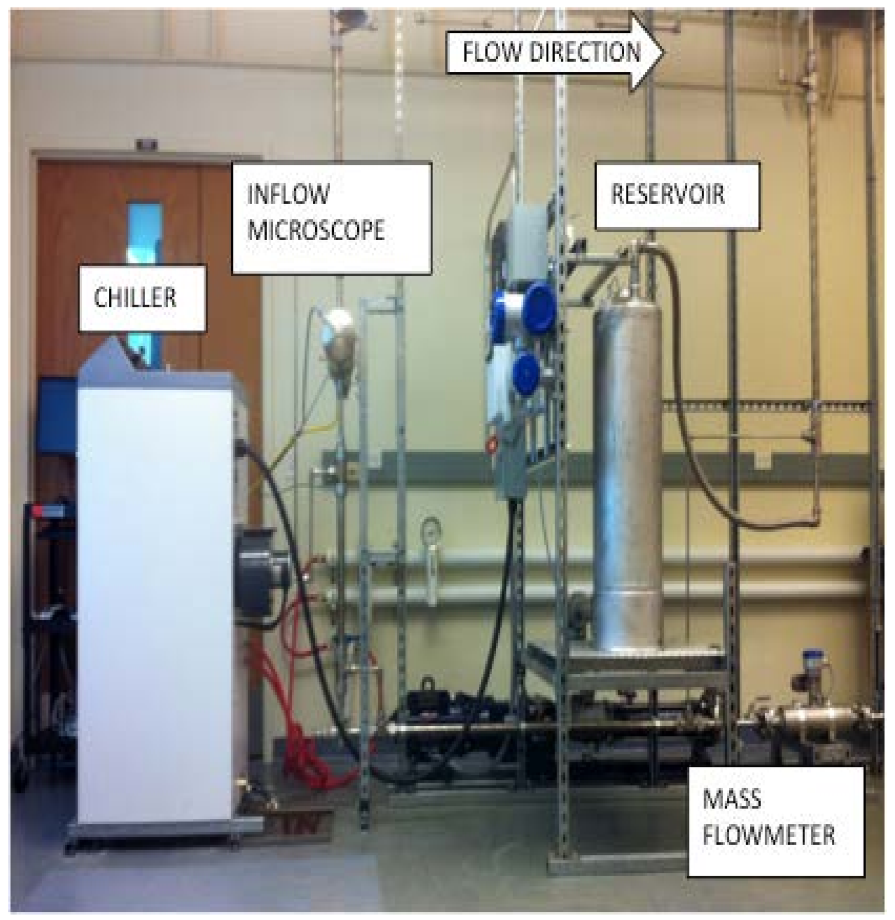
Motivation

- Formation and stability mechanisms still lacking for concentrated crude oil systems
- Millions of dollars spent on flow assurance management strategies
- Quantification of fundamental behavior will improve flow assurance strategies

Emulsions and Hydrates

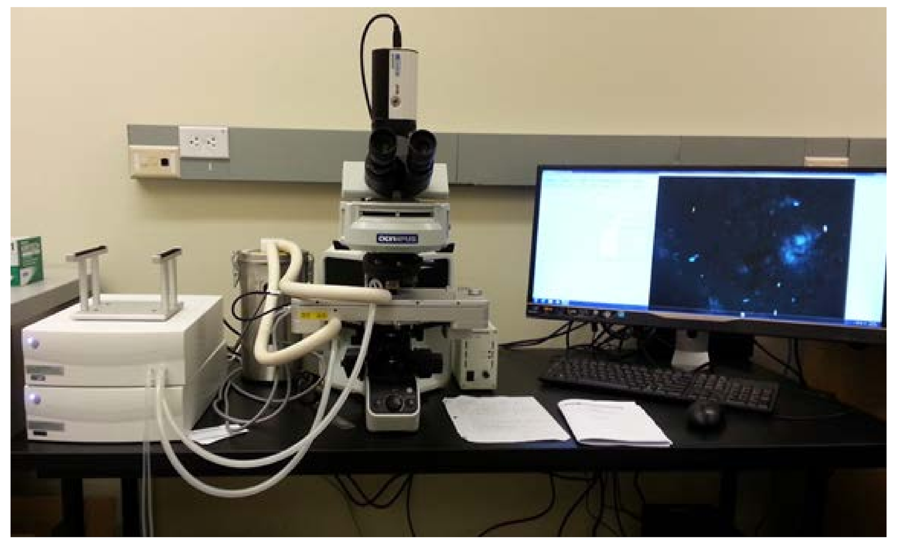
- Emulsion - Dispersion of two immiscible liquids stabilized using surfactant and/or solid particles
- Hydrates - Ice-like crystalline structure with low molecular weight gas compounds entrapped in water molecules
- Stabilizers – Chemicals used for stabilizing two immiscible liquids

Materials/Equipment



Flow loop setup used for investigating hydrates and emulsions under flowing conditions

- Operating Conditions
  - Max Pressure: 150 psig
  - Flow Rate: 20 gpm
  - Temperature: -30ºF to 200ºF
- 1" stainless steel jacketed tubing
- Capture real time images/video of the process fluid
- Particle range: 1 µm – 1 mm
- Efficient with concentrated emulsions and in flowing conditions
- Identify coalescence and adhesion
- Inflow microscope rated to 5,000 psig at 350 ºF



Olympus BX 53 polarized optical microscope with temperature controlled and shear stage

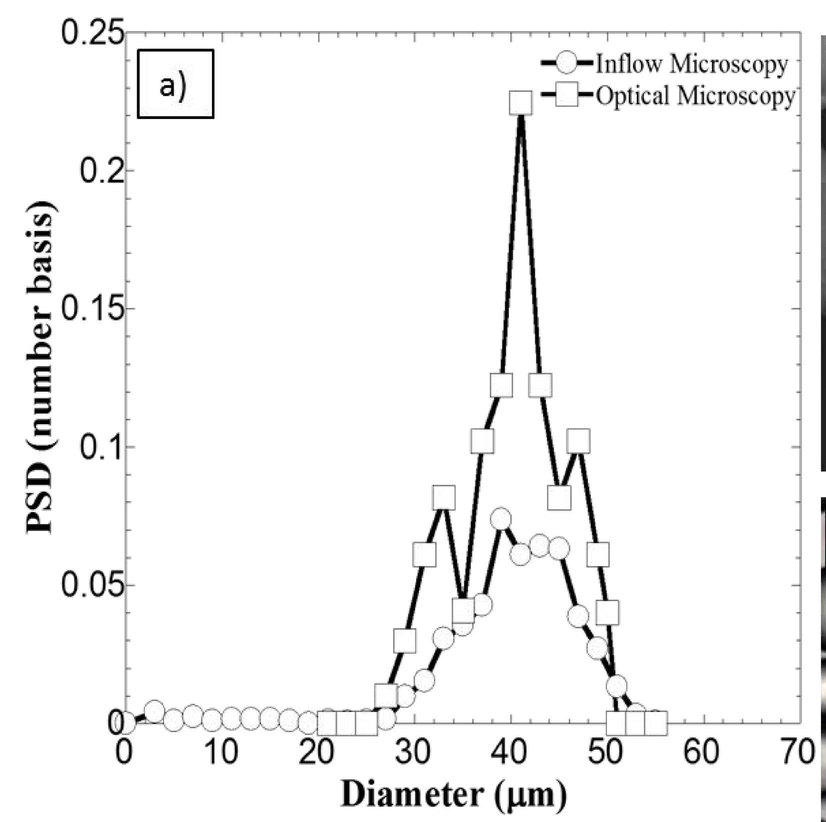
- Equipped with shear mixer and temperature control stage (-50 ° C to 450 ° C)
- Equipped with cross polarizing lens
- Images can be taken at 10X, 20X, and 50X magnifications
- Characterize hydrates and wax structure and morphology
- Characterize concentrated water-in-oil and oil-in-water emulsions

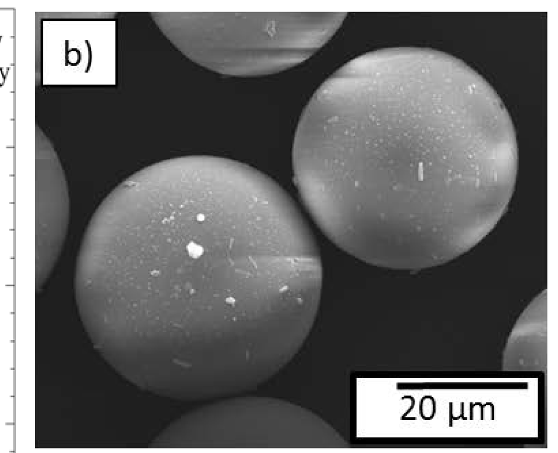
Emulsion Composition and Preparation

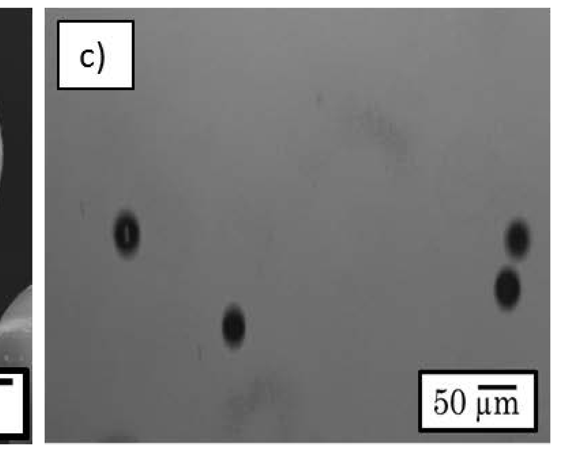
Component	% Volume
Crystal Plus 70T Mineral Oil	34.95
Cyclopentane	34.95
Aerosil R974/Span80	0.1
DI Water	30

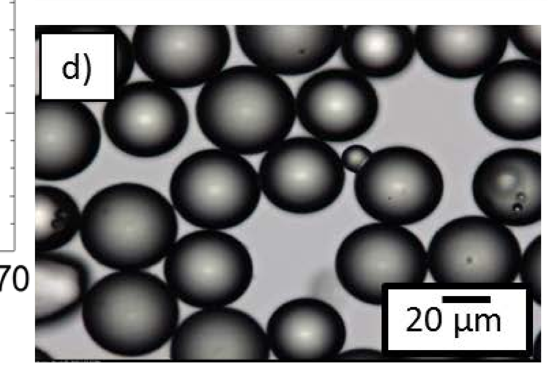
- Emulsions prepared using utlraturrax T25 homogenizer
- Mixing conditions, emulsion composition varied
- Dispersed phase (water) is added dropwise to the oil-surfactant mixture

Preliminary Results





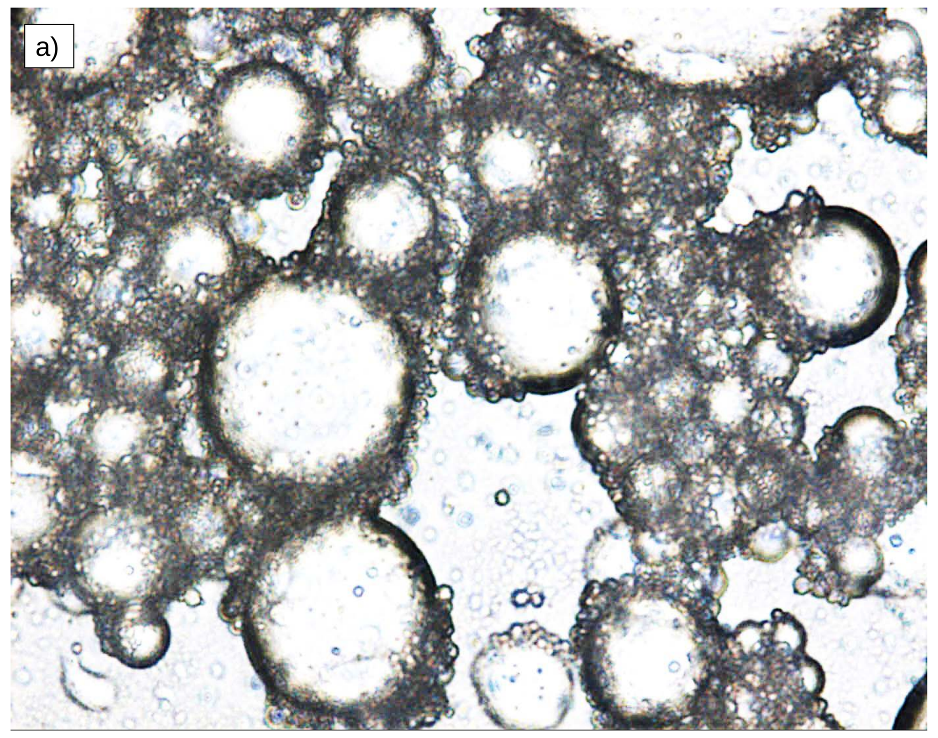


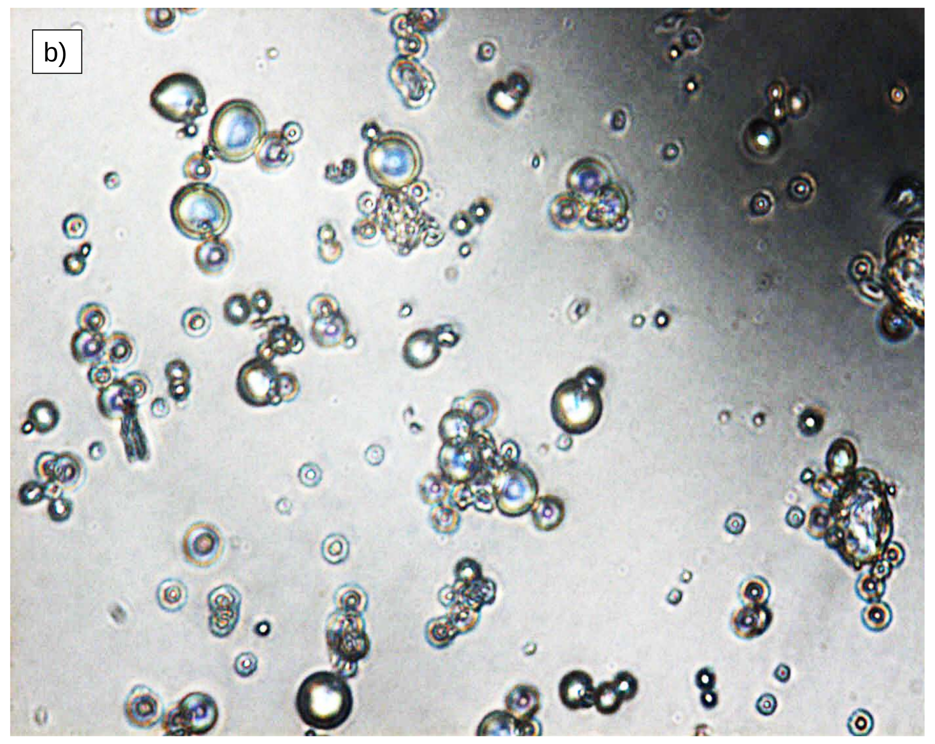


Method	Mean Particle Size (µm)
Inflow Microscopy	37.7
Optical Microscopy	40.5

Glass bead particle size distribution (psd) a) Comparison of psd using two different techniques (b) SEM of glass beads (c) Flow loop images of 5 wt.% glass beads in DI Water (d) Optical microscope images of glass beads

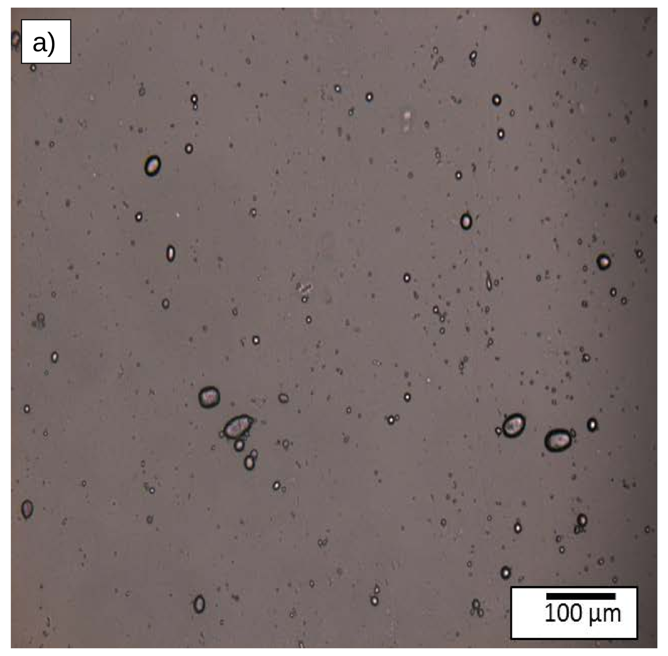
Bench top hydrate formation using a 40 vol% water-in-oil emulsion using Span80 a) before seeding (left) and b) after seeding (right)

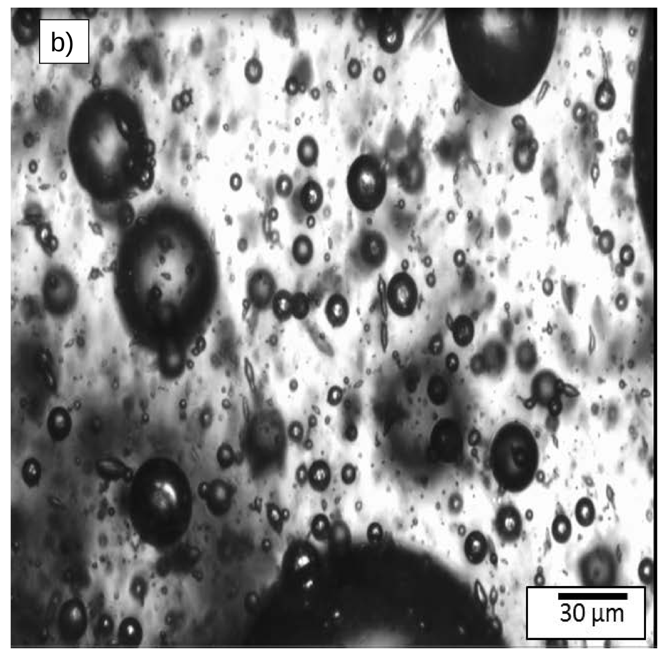




Optical microscopy images of 40 vol% water hydrate forming emulsions using a) Span80 (left) and b) Aerosil R974 (right). Images were taken at 50x magnification

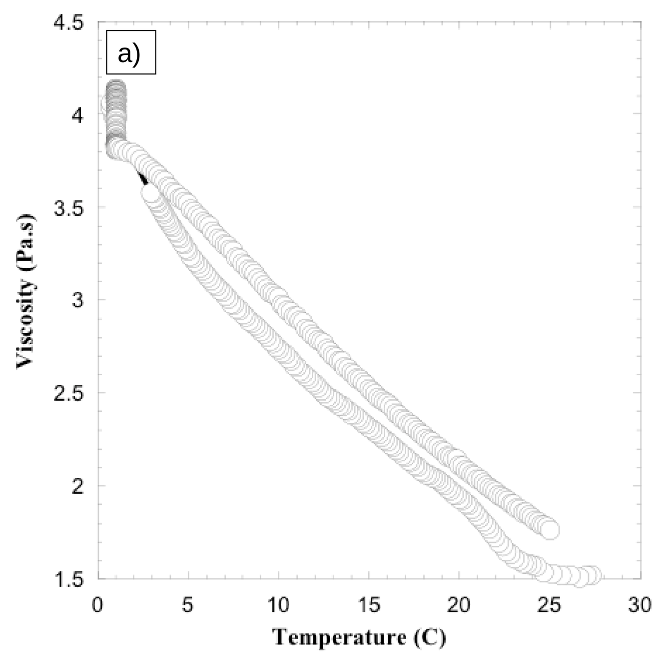
Emulsion Characterization

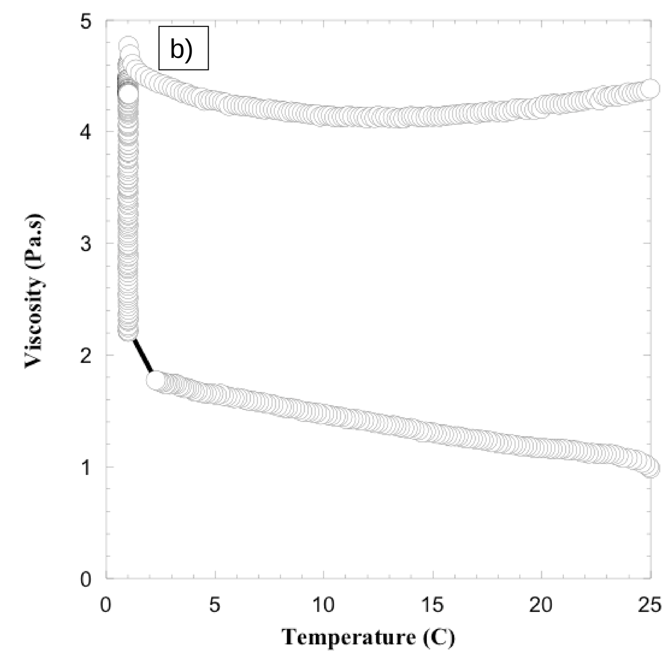




a) Optical Microscopy and b) Inflow Microscope images of 30 vol% water-in-oil emulsion stabilized using 0.1 vol% aerosil R974

Rheology of Hydrate Forming Emulsions





Rheology of 30 vol% water-in-oil hydrate forming emulsion stabilized using a) 0.1 vol% Span 80 b) Aerosil R974

Conclusion and Future Work

- Experimental capabilities at OSU are ideally suited for flow assurance (emulsions, hydrates, waxes, and asphaltenes)
- Inflow microscopy reveals details about droplet morphology in flowing conditions
- Investigate solids, salt, and emulsion breakers on transient emulsion/hydrate morphology

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