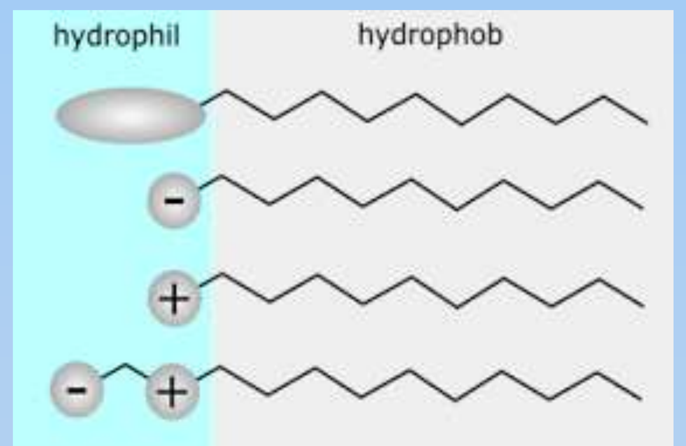
Determination of Surfactant Solution Viscosities with a Rotational Viscometer

Remelisa Esteves, Nonso Onukwuba and Dr. Birce Dikici (Advisor)
Mechanical Engineering Department, Embry-Riddle Aeronautical University

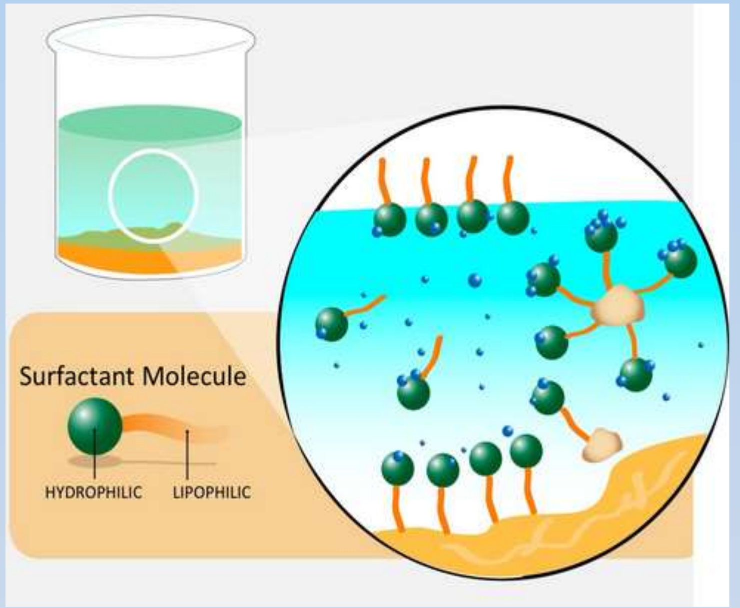
OBJECTIVE:
Surfactant solutions are used in engineering systems for improving boiling heat transfer. The purpose of this research is to determine the viscosities of surfactant solutions and to investigate the effect of composition on viscosity.

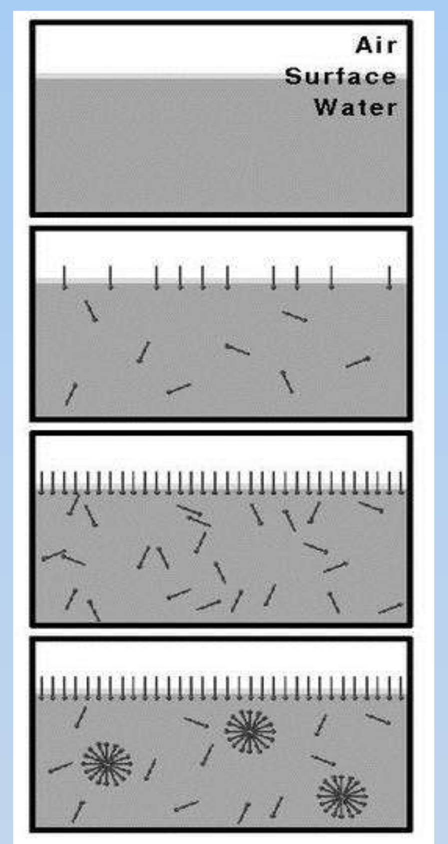
INTRODUCTION:
The nucleate boiling of water is important in engineering systems. It controls heat transfer within those systems, which helps prevent overheating. It is necessary to include additives (i.e. surfactants) in water to increase the number of nucleation sites and reduce wall temperature.

Surfactants:
Surfactants are compounds that lower the surface tension between two liquids or between a liquid and a solid. Surfactants may act as detergents, wetting agents, emulsifiers, foaming agents, and dispersants.



Surfactant classification: nonionic, anionic, cationic, amphoteric



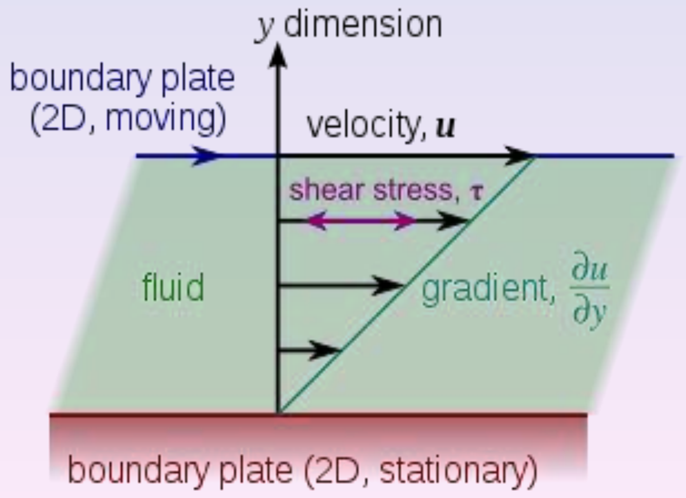


The process of CMC

Viscosity:
The viscosity of a fluid is a measure of its resistance to gradual deformation by shear stress.

$$\tau = \mu \frac{du}{dy}$$

where
τ=Shear stress(N/m^2)
μ=Viscosity (kg/m.s, N.s/m^2, or Pa.s)
du/dy= Rate of deformation (s^{-1})



EXPERIMENTS:
The surfactants used were SLS, EH-14, and SA-9.

SLS

EH-14

SA-9

Sodium lauryl sulfate (SLS) is an anionic surfactant, used as a foaming and cleaning agent in detergent, wetting agent in textiles, cosmetic emulsifier, and sometimes in toothpastes.

ECOSURF™ EH-14 is a nonionic surfactant. It has many applications, such as hard surface cleaners, metal cleaners, high performance cleaners, industrial processing/manufacturing, and agricultural formulations.

ECOSURF™ SA-9 is a seed oil surfactant and a biodegradable nonionic surfactant . This type of surfactant provides considerable benefits in handling, processing, and formation. It is used in hard surface cleaners, prewash spotters, and paints and coatings .

A precision scale was used to ensure consistent measurements of water and surfactants.
PPM is a unit of measurement, which means parts per million.

$$\text{ppm}=1{,}000{,}000\ \frac{m_c}{m_s}$$

where
m_c = mass of component (kg)
m_s = mass of solution (kg)

A magnetic stirrer was also used to ensure thorough mixing of the surfactant and water.
Gloves, lab goggles, lab coats, beakers, small scoops and pipettes were also used during these procedures.

The mass of water that was used to mix all the surfactants was constantly 400 g throughout the experiment. The first measurement of the surfactant, which was 20 mg of SLS, was thoroughly mixed in a beaker (50ppm) with a magnetic stirrer. Next, the rotor of the viscometer was placed in a beaker with the mixture. These steps were repeated for the SLS at different compositions and the other surfactants at different compositions.

A rotational viscometer measures viscosity from a rotating cylindrical rotor. The reason why there are different sized rotors is because the torque created by the rotor on the fluid is dependent on the radius of the rotor. The rotational viscometer determines the torque required to rotate the rotor at a constant speed while immersed in a fluid. By measuring the torque, the fluid shear stress at any point of the rotor can be found, thus viscosity can be determined.

After each trial, the rotor and its casings were detached and washed out. The beakers and other equipment were also washed out and dried to avoid skewed data. This process was carried out for the remainder of the experiments.

ERROR ANALYSIS AND CONCLUSION
To verify the consistency in the measurements, the percentage differences were determined.

$$\%diff = \left|\frac{\mu_{t1} - \mu_{t2}}{\frac{\mu_{t1} + \mu_{t2}}{2}}\right| .100\%$$

where
μ_{t1} =viscosity of surfactant solution at trial 1
μ_{t2} =viscosity of surfactant solution at trial 2

The percentage differences fell within 5%, which indicates that the data was nearly consistent.

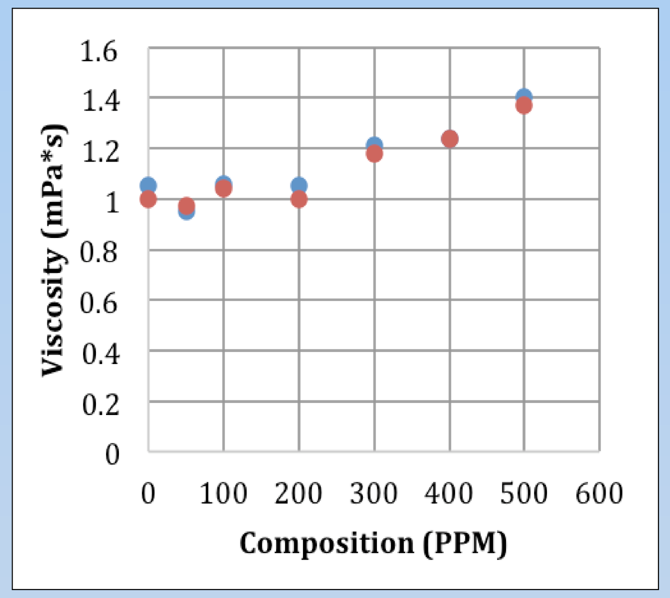
The percentage errors of the viscosities of each solution at 0 PPM were calculated because they slightly deviated from the theoretical viscosity of water at room temperature.

$$\%error = \left|\frac{\mu_{exp} - \mu_{theory}}{\mu_{theory}}\right| .\ 100\%$$

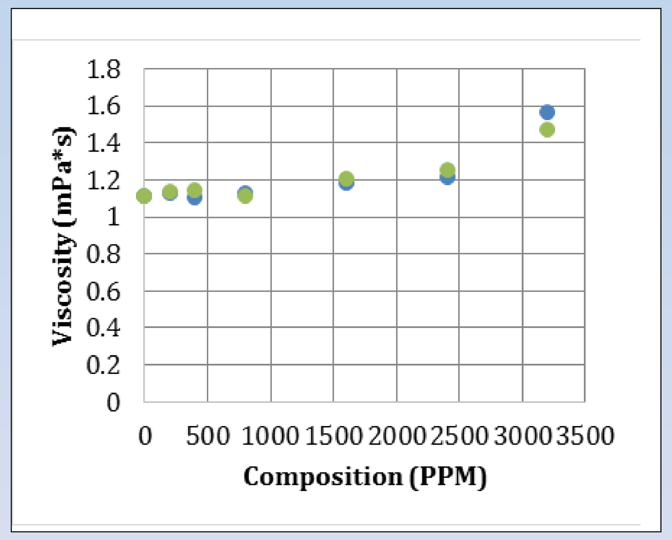
where
μ_{exp}= the measured viscosity of water
μ_{theory} = the theoretical viscosity of water.
(tabulated value of viscosity of water at 20° C is 1.002x10^{-3} Pa.s from reference tables)

Surfactant	Percentage Error Trial 1	Percentage Error Trial 2
SLS	4.79%	0.200%
EH-14	10.7%	10.7%
SA-9	9.78%	9.78%

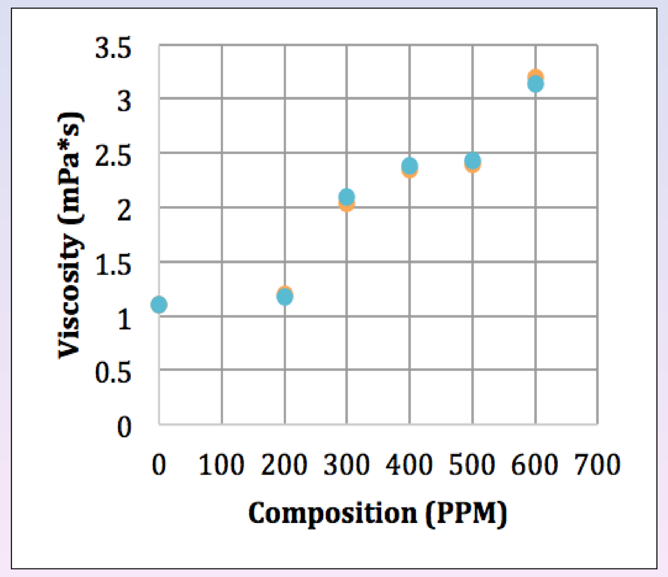
SLS, EH-14, and SA-9 had a nearly consistent pattern as their compositions increased. The approximate maximum viscosity measured was 1.39 mPa. s for SLS, 1.52 mPa.s for EH-14, and 3.17 mPa.s for SA-9. The viscosity of surfactant increases with the concentration in the given concentration intervals.



SLS



EH-14



SA-9