Determination of Surfactant Solution Viscosities with a Rotational Viscometer
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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.

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

ECOSURFM™ 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.

ECOSURFM™ 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.

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

\[ \tau = \mu \frac{dx}{dy} \]

where
- \( \tau \) = shear stress (N/m²)
- \( \mu \) = viscosity (kg/m·s, N·s/m², or Pa·s)
- \( \frac{dx}{dy} \) = rate of deformation (s⁻¹)

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 (500pm) 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.

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.

\[ \%\text{error} = \left( \frac{\mu_{\text{meas}} - \mu_{\text{theory}}}{\mu_{\text{theory}}} \right) \times 100\% \]

where
- \( \mu_{\text{meas}} \) = the measured viscosity of water
- \( \mu_{\text{theory}} \) = the theoretical viscosity of water.

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

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

\[ \%\text{diff} = \left( \frac{\mu_1 - \mu_2}{\mu_2} \right) \times 100\% \]

where
- \( \mu_1 \) = viscosity of surfactant solution at trial 1
- \( \mu_2 \) = viscosity of surfactant solution at trial 2

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

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

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

\[ \%\text{diff} = \left( \frac{\mu_1 - \mu_2}{\mu_2} \right) \times 100\% \]

where
- \( \mu_1 \) = viscosity of surfactant solution at trial 1
- \( \mu_2 \) = viscosity of surfactant solution at trial 2

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