Dynamic Surface Tension of an Aqueous Detergent Solution Determined by Maximum Bubble Pressure Technique

Processes such as foaming, cleaning, printing, and coating involve fast and dynamic interactions at the gas, liquid and solid interfaces. In these processes, the dynamic surface tension of the interface can be more insightful than the equilibrium surface tension value, as in the case of a solution with surfactant. The function of the surfactant is to lower surface tension in order to aid wetting; it is imperative that the surfactant molecules reach the interface during the time of the process. How can one measure to make sure the surfactant molecules have sufficient time to move during the process? The answer is to use the maximum bubble pressure dynamic surface tensiometer. The maximum bubble pressure technique for dynamic surface tension measurements creates dynamic interfaces (gas bubbles in a solution) between gas and liquid during testing, which enables the user to study the efficiency of surfactants in solutions.

The BP-D5 Automatic Dynamic Surface Tensiometer made by Kyowa Interface Science Co. Ltd. (Tokyo, Japan) is used in this study. The BP-D5 employs the Maximum Bubble Pressure Method by sparging a solution containing surfactant at a variable or constant flow rate. The sparging device is a capillary probe with a known inner radius. As the gas flows through the capillary, a bubble begins to form on the capillary tip. As the bubble forms, the radius of the bubble decreases over time until it reaches its minimum when the radius of the bubble equals the radius of the capillary. At this time, the bubble also reaches its maximum pressure. With a known or measured value for the capillary radius, the probe submerge depth, the liquid density and the maximum bubble pressure, the surface tension of the liquid can be determined via the Young-Laplace equation. On the BP-D5, and shown in Equation 1, the dynamic surface tension can be determined using a reduced Young-Laplace equation from the ratio of the maximum bubble pressure between the surfactant solution and the calibration liquid.

Eq. 1
$$\gamma(t) = \frac{\gamma_{calib}}{P_{calib}(t)} p(t)$$

Where t is the gas bubble lifetime, $\gamma(t)$ is the surface tension of surfactant solution at lifetime t, γ_{calib} is the surface tension of the calibration liquid, p_{calib} (t) is the maximum bubble pressure of the calibration liquid at lifetime t and p(t) is the maximum bubble pressure of surfactant solution at lifetime t.

The BP-D5 has two modes of operations: 'variations over time' and 'time specified mode'. 'Variations over time' gradually reduces the sparging flow rate and plots the surface tension against the bubble lifetime. 'Time specified mode' keeps the sparging flow rate constant, thus keeps the bubble lifetime constant, and measures the dynamic surface tension at this specific lifetime.

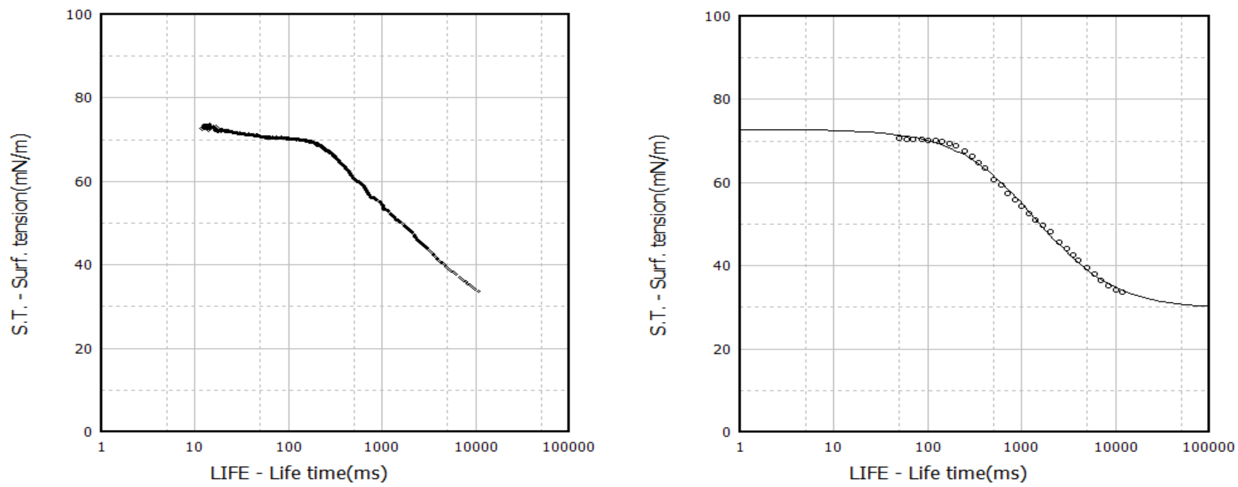

Figure 1. Dynamic surface tension determined using the Maximum Bubble Pressure Method for a detergent aqueous solution; raw data (left) and averaged data (right) with a Rosen fit applied.

Figure 1 presents the dynamic surface tension values of a 400 ppm concentrated dishwashing detergent aqueous solution, determined by the 'variations over time' mode available on the BP-D5. From Figure 1, it can be seen that surface tension values of the detergent solution change significantly with the change of the lifetime of the gas bubbles. The faster the bubbles are generated the higher the measured surface tension. When the bubble lifetime is short, the surface tension of the detergent aqueous solution is approximately 72 mN/m; so close to the surface tension value of pure water. When bubble lifetimes are above 100 ms, the surfactant has time to migrate to the interface and lower the surface tension. Further, as predicted by the Rosen fit, when sufficient time is allowed, the surfactant in the detergent solution could reduce the surface tension down to approximately 30 mN/m.