The Spinning Drop Video Tensiometer (SVT)

Determination of Low Interfacial Tensions with the DataPhysics Instruments Spinning Drop Video Tensiometer

The determination of low and ultra-low interfacial tension (IFT) of liquids has attracted more and more attention, due to its importance in many applications, e.g. enhanced oil recovery and the development of new surfactant. As known, the interfacial tension of liquids can be determined by optical analysis of the drop shape with the pendant drop method, or with a tensiometer with Wilhemly plate or Du-Noüy ring. However, low interfacial tensions cannot be measured correctly with these methods. To determine low to ultra-low interfacial tensions properties between liquids, DataPhysics Instruments has developed Spinning Drop Tensiometers (SVT, Fig. 1) that guarantee an efficient measuring procedure as well as the highest precision and reproducibility of the measuring results.

Fig. 1. Spinning Drop Tensiometer, DataPhysics Instruments

Keywords: Spinning Drop Tensiometer SVT ▪ Low/Ultra-low Interfacial Tension ▪ Oil ▪ Surfactant

Technique and Method

The spinning drop video tensiometers of the SVT series are special-purpose optical instruments for measuring extremely low interfacial tensions and rheological properties. This measuring technique offers unrivalled possibilities for the analysis of surfactant effectiveness in the development of emulsions or in the enhanced oil recovery.

The method is based on the optical contour analysis of a drop. As shown in Fig. 2, the drop, instead of hanging from a dosing needle and being exposed to gravitation, is located inside of a rotating capillary.

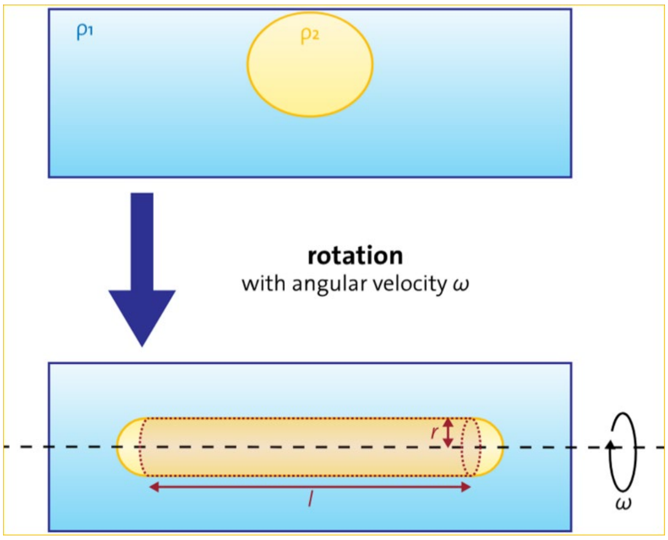

Fig. 2. Drop deformation with the spinning drop principle

Due to the rotation of the measurement capillary the liquids separate depending on their density. The denser liquid is going to be pushed out of the centre, while the less dense liquid will form a drop at the rotation axis. The elongation of the drop is depending on the interfacial tension between the liquids. A lower interfacial tension will result in a more elongated shape of the drop, whereas a higher interfacial tension results in a more centred drop. While increasing the rotation speed the drop will become flat caused by the stronger forces on the denser liquid. Hence, the drop is deformed cylindrically and its interfacial area increases. The interfacial tension counteracts this area increase and thus is determined by analysing the equilibrium drop shape. In combination with the SVT software, the determination of low to ultra-low interfacial tensions and rheological interface properties can be conducted efficiently, reliably and reproducibly.

Therefore, with the Spinning Drop Tensiometer, the interfacial tension of a surfactant solution and an organic oil has been determined in this application note.

Experiment

At the beginning of each measurement, the surfactant solution (denser liquid) is filled in the capillary first. While filling the capillary, it is important to make sure that there are no air bubbles in the system. To ensure the air bubble free closing of the capillary, a special closing mechanism has been developed. Through a syringe opening within the screw tap, the organic oil (less dense liquid) can be added. Notably, the volume of organic oil should not exceed a few µl, so that the drop can be positioned in the middle of the capillary.

After a successful preparation of the capillary, it is easily fixated in the measurement cell due to the fast-closing mechanism of the SVT.

For the measurement, the camera has to be focused on the rotating drop. Therefore, a suitable magnification has to be chosen. With the automatic and software-controlled tilting of the measurement cell, the drop will be held in a stationary position. In addition, the drop can be automatically held in the centre of the camera, by automatic drop shape recognition and a depending camera movement to compensate drifting effects of the drop. Due to the stable drop shape, the software is able to determine the magnification factor of the system automatically by correlating a given driving distance of the camera with the change in pixels of the image.

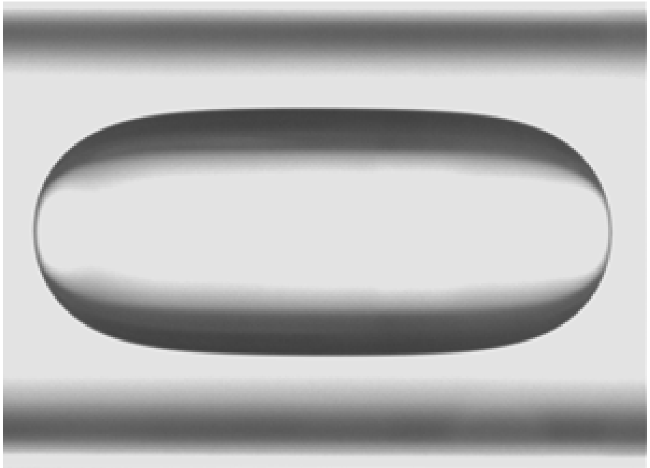

Fig. 3. Oil drop at 6000 rpm

Fig. 4. Image section of the above drop at 10000 rpm

Variation of the rotational speed of the capillary can influence the elongation of the drop. The shape of the drop becomes more cylindrical for higher rotational speeds. Different drop shapes for a surfactant-oil system with rotational speeds of 6000 and 10000 rpm are shown in Fig. 3 and Fig. 4. The software enables the possibility to calculate the interfacial tension between the liquids according to different image sections. If the elongated drop is bigger than the displayed image section it is possible to calculate the interfacial tension by analyzing the left or right end of the drop, or even by the cylindrical mid stage of the drop.

Furthermore, the rotational speed of the capillary has to be high enough so that the influence of the buoyant force on the shape of the drop is negligible. By knowing the rotational speed and liquid specific data like, density and refractive index, the interfacial tension can be calculated through different calculation algorithms.

Results

The measurement was done with 6000 rpm and at a controlled temperature of 25 °C. The drop shape was recorded 150 times and the resulting interfacial tension of the liquids has been calculated by using different methods, *i.e.*, “Cayias, Schechter, Wade (CSV)”, “Laplace Young” and “Vonnegut”. The results are shown in table 1.

Table 1. Interfacial tension between surfactant and oil calculated by different methods.

Calculation Method	IFT [mN/m]
CSV	0.821 ± 0.026
Laplace Young	0.822 ± 0.025
Vonnegut	0.815 ± 0.026

As table 1 shows, the interfacial tension between the liquids is almost identical for the three different calculation algorithms. The IFT differences of these three calculation methods are well within the margin of error given by the standard deviation. Therefore, The Spinning drop video tensiometer SVT is suitable for the analysis of low to ultra-low interfacial tensions with high precision and reproducibility.

Summary

By using a DataPhysics Instruments Spinning Drop Tensiometer, the low interfacial tension between surfactant and oil could be determined easily and reliably.

Therefore, the SVT technique provides a fast and efficient way to determine low interfacial tension between liquids with a high reproducibility. It has become an essential tool for improving enhanced oil recovery and for the analysis of surfactant effectiveness in the development of emulsions.

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