Application note

Studying the stability and kinetics of fast-breaking foam using face cleansing foam as example

dataphysics
Understanding Interfaces

Cosmetics, detergents, and pharmaceuticals are often applied as foam due to its good spreading ability and its anti-stick properties. Many cosmetic manufacturers strive to develop foaming products, because consumers often consider foaming cleaning products as being of higher quality and providing better usability. Their stability has a significant influence on their applications. Foams consist of gas bubbles that are dispersed in a liquid phase. Because of various destabilisation mechanisms they are usually quite unstable. In the case of face cleansing foam, fast-breaking foam bubbles are desired to enable easy utilisation. Therefore, it is important for the formulation designer to understand the kinetics of the foam breaking process. However, it is very difficult to characterise this process owing to its rapid changes. The MultiScan (MS 20) from DataPhysics Instruments, a compact and versatile measuring device for optical stability and aging analyses, can overcome this difficulty. It provides the possibility to study the stability and kinetics of foams easily and conveniently. In this application note, we study the kinetics of the drainage phase and foam breaking of a face cleansing foam using the MS 20.

Fig. 1: Face cleansing foam belongs to the category of fast-breaking foam.

Keywords: MultiScan MS 20 ▪ Stability Analysis ▪ Average Bubble Diameter ▪ Bubble Size ▪ Foam ▪ Drainage

Technique and Method

The MultiScan MS 20 (Fig. 2) from DataPhysics Instruments is a measuring device for automatic optical stability and aging analysis of liquid dispersions and the comprehensive characterisation of **time- and temperature-dependent destabilisation mechanisms**. It consists of a base unit and up to six temperature-controlled sample chambers (ScanTowers), which can be individually controlled at temperatures between 4 °C and 80 °C.

With its accompanying software MSC, the MS 20 is a perfect partner for stability analyses, since even the slightest changes within dispersions can be detected and evaluated. Thus, the MS 20 enables a fast and objective evaluation of transmission and backscattering intensities, using DataPhysics Instruments' so called 'Values method'. Additionally, based on the evaluated backscattering-intensities, the MSC-software can evaluate mean particle and bubble sizes using either the backscattering-method or Monte-Carlo-method. Thus, MS 20 is the ideal device for studying the kinetics of foam breaking.

Fig. 2: DataPhysics Instruments stability analysis system MultiScan MS 20 with six independent Scan Towers

Experiment

A commercial face cleansing foam was used as sample in this study. The sample was shaken and immediately poured in a transparent glass vial. To ensure the vial was fully filled with foam, it was gently vibrated. Then it was placed into an MS 20 tower and measured at T = 30 °C every 13 s for 1 h 22 min. The measured zone was between 0 mm (bottom of the vial) and 57 mm (top of the vial).

The pictures at the left and in the middle of Fig. 3 show the sample vial at the end of the measurement and after the foam completely broke down. Based on the initial sample volume and the final liquid volume (Fig. 3 middle), the foam volume concentration can be calculated to have been around 90 %. To confirm the reliability and accuracy of the results, the changes of the foam were also observed on a glass slide under an optical microscope (Fig. 3 right). However, this technique requires time-consuming analyses to yield accurate data. Additionally, the bubbles may interact and break differently on a glass slide than within a glass vial. In this specific case, we assume that the bigger bubbles have broken before taking pictures of the foam and are therefore not visible in the picture.

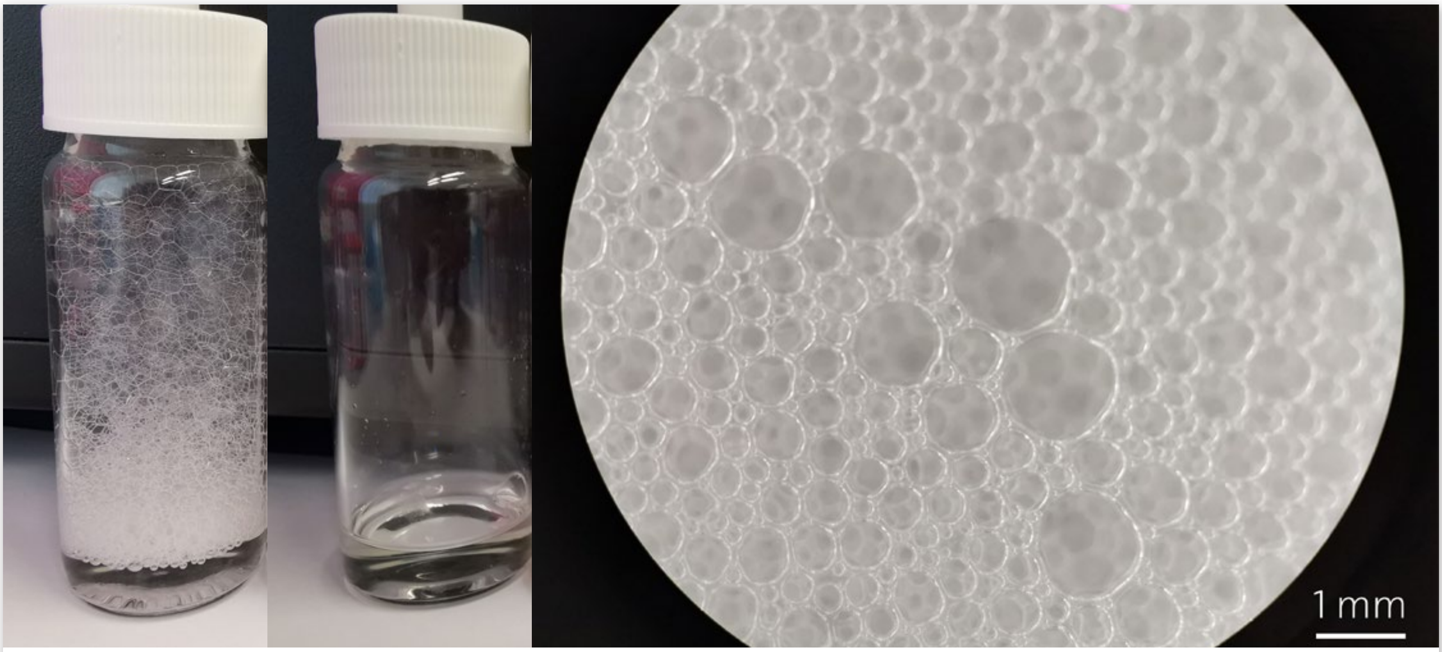

Fig. 3: The sample vials at end of the measurement (left) and after all foam has broken down (middle). The picture on the right shows the foam under a microscope.

Results

Fig. 4 plots the transmission and backscattering intensities against their position. Those values are used for the foam stability analyses. As Fig. 4 shows, the transmission-intensities increase sharply to 125 % near the vial bottom, specifically between 0.5 mm and 7 mm of the measured height.

Since the system was referenced with an empty vial the transmission signal can increase above 100 % due to the higher refractive index of the liquid. The increasing transmission intensity indicates that this zone becomes the drainage phase, where the liquid, which is released once bubbles burst, accumulates over time.

In addition, the transmission-intensities increase faster in the top layer compared to the middle layer. This suggests that the bubbles coalesce faster in the top layer than in the middle layer due to gravity and differences in pressure.

More conclusions can be drawn: the diagram in Fig. 4 shows that the backscattering-intensities decrease globally over time, indicating that a coalescence of bubbles occurred and that the bubbles then broke when reaching a certain size.

With the 'Values'-method and 'Single Position'-function in the MSC-software, the change of the backscattering-intensities at a defined position (e.g. 10 mm) can be analysed utilising absolute backscattering-signals. The graph at the top of Fig. 6 depicts a dramatic change of backscattering-values in the first 10 minutes. After 1 h, the values remain almost constant, which is consistent with the results obtained by looking at the transmission intensity values earlier in this note.

Furthermore, the kinetic analysis of the liquid drainage phase at the lower layer of the vial (Fig. 5) reveals that the drainage layer is around 5 mm thick and that changes in its peak width are more pronounced in the first 10 minutes.

Once the initially present larger bubbles have broken the draining slows down since the coalescence of the smaller bubbles takes increasingly longer time.

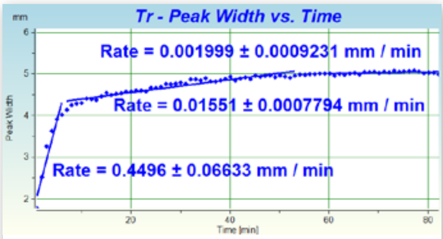

Fig. 5: Kinetics of liquid drainage phase

After 1 h, the peak width change stays constant with a rate of 0.002 mm/min, indicating that most of the foam has broken down. This is consistent with the observations of the sample vial at the end of the measurements and after all foam has broken down (Fig. 3 left and middle).

Based on the backscattering-intensity values, the average bubble diameter over time can be easily obtained within the software (Fig. 6 bottom). The resulting mean bubble diameter diagram clearly shows that the size of the bubbles increases until the bubbles break down. For the calculation, we assumed that the refractive indices of solvent and foam were 1.33 (water) and 1 (air), respectively. In addition, the Monte-Carlo-method can be applied using the MSC-software

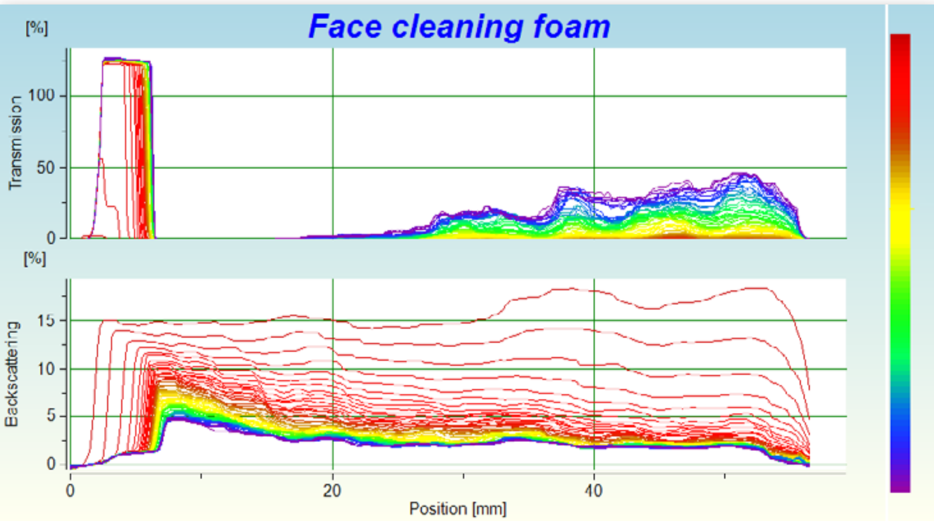

Fig. 4: Transmission and backscattering diagrams of the studied face cleansing foam

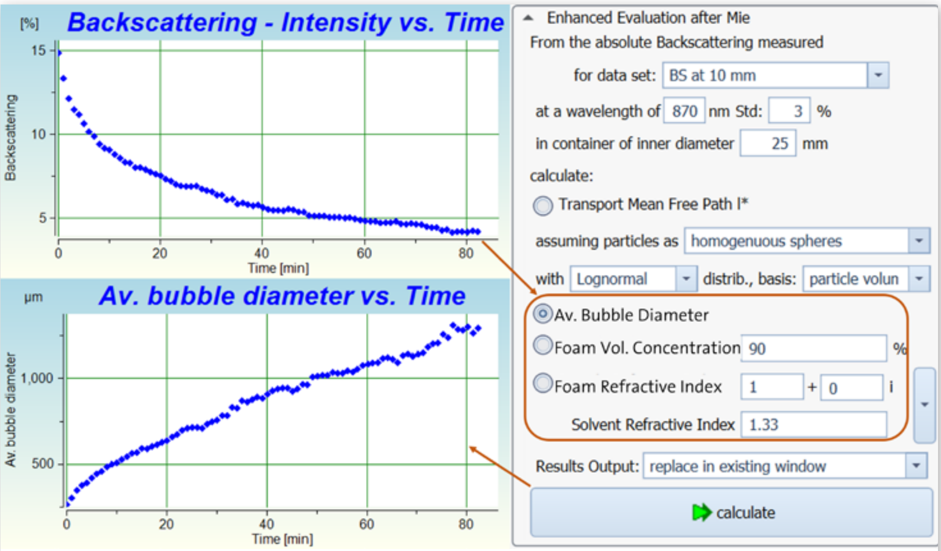

Fig. 6: Evaluation of the values of backscattering intensity and mean bubble size at the position of 10 mm over time for studied face cleansing foam

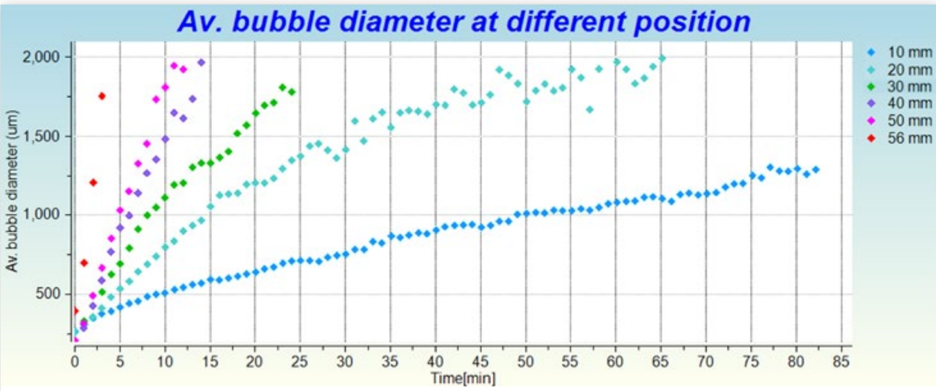

Fig. 7: The overlay of the average bubble diameters at different positions over time

to calculate mean bubble sizes, as the literature has shown that it is more reliable over all parameter ranges.

To have an insight into the breaking kinetics of the foam, the mean foam bubble size at different positions was evaluated. Thanks to the overlay function of MSC, all results can be displayed in one window. As shown in Fig. 7, it takes less than 15 minutes for the average bubble diameter to increase from 250 µm to around 2000 µm and then collapse in the top layer above 40 mm.

However, in the bottom layer at 10 mm it takes 80 minutes for the average bubble diameter to increase to around 1500 µm and the bubbles to break. This is again consistent with the previous analyses.

Summary

The MultiScan MS 20 stability analysis system and its MSC-software provide a **fast and simple way** to study the **stability and kinetics of quick-breaking foam**. Changes can be detected sensitively and objectively. This enables cosmetic, detergent and pharmaceutical formulation designers to anticipate and quantify stability issues time- and cost-effectively.

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