Application Note
V-204

Optimization of the filling process of shampoo sachets with the HAAKE CaBER 1 Rheometer

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- Shampoo
- filling
- elongational viscosity
- stringiness
- HAAKE CaBER

Abstract

With certain shampoo formulations, ‘strings’ of shampoo are formed when filling sachets during production. This causes the product to spill across the sachet seam area. As a consequence, the sachet cannot be properly sealed. Using the HAAKE CaBER 1 extensional rheometer ‘string forming’ shampoo formulations were easily and quickly distinguished from ‘well performing’ samples. Rotational rheometers were not able to provide this information.

Introduction

While most commercial rheometers are capable of generating only shear flows, in many industrial processes and applications the flow is predominantly extensional in nature. Typical examples of this type of flow are fiber spinning, paper coating, extrusion and filling food or toiletries in bottles. This paper describes the optimization of filling shampoo into sachets. With certain shampoo formulations, ‘strings’ of shampoo are formed when filling the sachets, which causes the product to spill across the seam area. As a consequence, the sachet cannot be properly sealed. This failure is expensive as it will result in the disposal of many improperly sealed sachets.

Using classical rotational or oscillatory shear experiments, no discernible differences could be observed between the five shampo of ormulations investigated. The use of the HAAKE CaBER 1 (Capillary Breakup Extensional Rheometer) however, allowed the characterization of the formulations’ extensional properties in a quick and easy experiment, thus providing a solution to the problem.

Shampoos consist of 80 -90% water with more then 2% detergent, foaming agents and about 1% fragrances and preservatives [1]. Often shampoos contain antistatic agents, thickeners and conditioners [2]. Current health and beauty trends make it important to stabilize special-effect particles in gels, body washes or shampoos, hence the addition of thickeners to prevent the sedimentation of these particulate phases [3]. A problem with thickeners, however, is that they can be the cause of unwanted extensional properties, i.e. they can cause string formation.

These unwanted rheological properties can manifest themselves in an unpleasant and ”slimy” feeling while using the product. They can also cause string formation during the high speed filling of shampoo into sachets or bottles, resulting in improper sealing of the sachet or messy bottles. Slowing down the filling speed would solve the problem, but that has implications for the throughput capability of the production line. A far better solution would be to modify the formulation of the shampoo in such a way that the highest filling speed can be used.

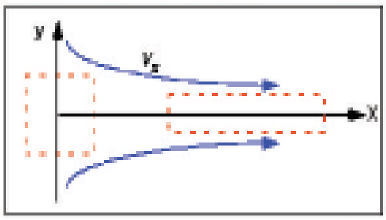
In this investigation five shampoos with different formulations were tested to find out which formulation could be filled into the sachets successfully at a high filling speed. All formulations were previously tested on a high speed packing line with differing degrees of success. Some exhibited the string formation problem that resulted in failure of the sachet seams.

Experimental

The measurements were carried out with the HAAKE CaBER 1 extensional rheometer. The CaBER experiment gives a quick insight into the material properties under an extensional deformation which occur, for example, during the sachet filling. It impossible to determine the extensional properties of a fluid using a traditional rotational rheometer.

In an extensional flow the streamlines converge and the velocity increase (i.e. the acceleration) is in the direction of the flow (Figure 1a). This in contrast to the situation in a shear flow where the streamlines are parallel and the velocity increase is perpendicular to the direction of the flow (Figure 1b).

a)



b)

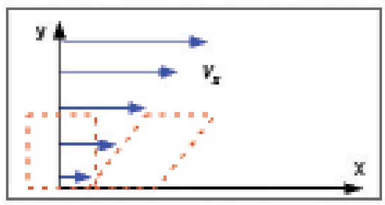


Figure 1: Comparison between extensional flow (a) and shear flow (b).

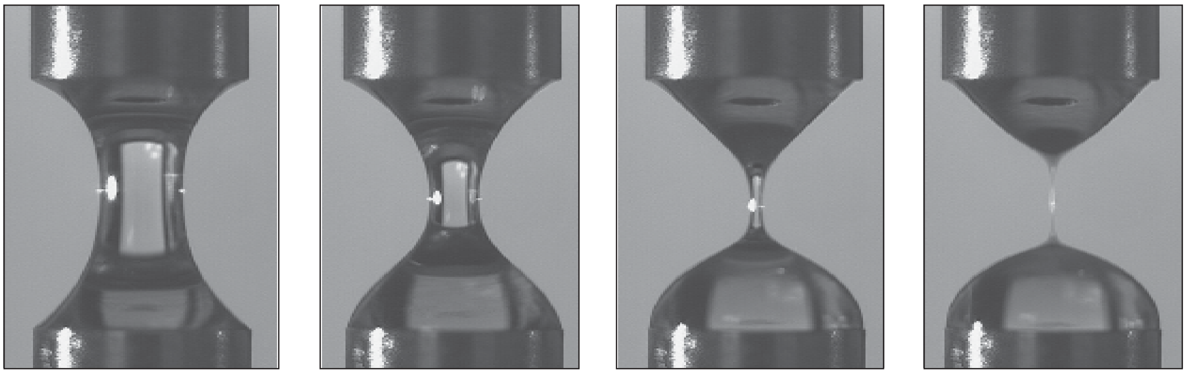


Figure 2: Sequence of a CaBER measurement.

The principle of the CaBER experiment is simple. A small quantity of sample (less than 0.2 ml) is placed between two parallel plates (diameter e.g. 6 mm). The fluid is then exposed to a rapid extensional step strain by moving the upper plate upwards, thereby forming a fluid filament (Figure 2).

The filament evolution as a function of time is controlled by the balance of the surface tension and the viscous and elastic forces. The surface tension is trying to "pinch off" the filament while the extensional rheological properties of the fluid are trying to prevent that. A laser micrometer measures the midpoint diameter of the gradually thinning fluid filament after the upper plate has reached its final position (Figure 3).
From the measured data, which describes the evolution of the filament diameter as a function of time (Figures 2a, 2b and 2c), the filament break-up time (Figure 2d), the extensional deformation and deformation rate and extensional viscosity can be calculated.

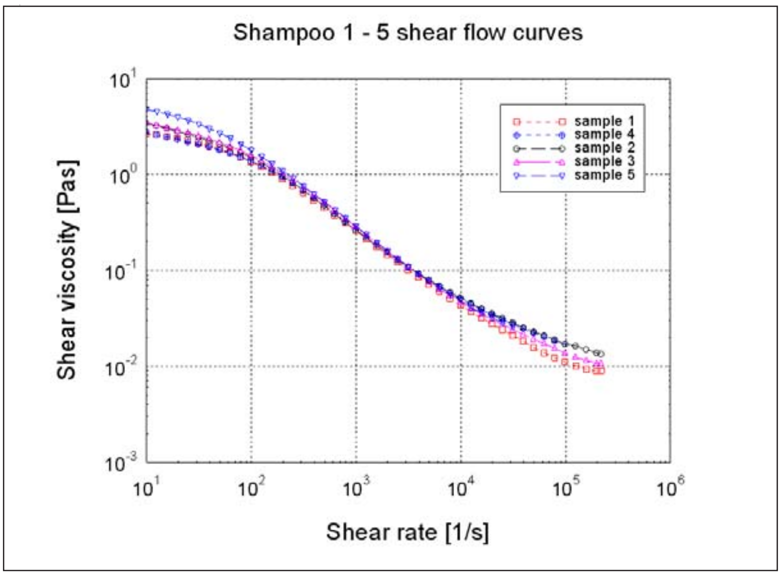


Figure 4: Shear viscosity curves of shampoos 1-5.

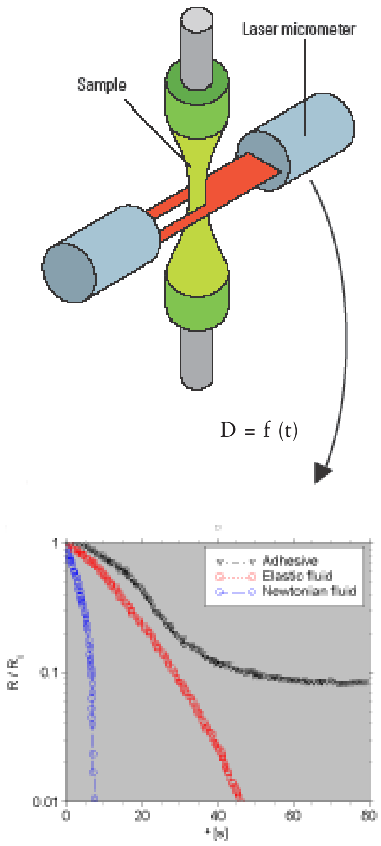


Figure 3: Principle of the CaBER experiment.

Results and Discussion

Five different shampoo samples were measured. Two of the samples (samples 1 and 2), performed well in the sachet filling equipment; the three other samples (samples 3, 4 and 5) did not perform well.

When measured in a rotational rheometer, the five samples did not show any differences in the flow curves that could explain their different during the filling of the sachets (Figure 4).

In contrast, when measured in an extensional flow using the HAAKE CaBER 1 rheometer, the measured diameter versus time curves (see Figure 5) of the five samples nicely rank according to their filling behavior: the shorter the filament lifetime in the CaBER experiment, the better the filling properties.

The 5 samples clearly differentiated in extensional flow. The filament lifetimes of shampoos 1 and 2 are relatively short. These shampoos can be filled into sachets without any obvious problems. For shampoos 3, 4 and 5, the filament lifetimes are significantly longer, which leads to problems in sachet filling. String formations prevented the sachets sealing, a problem which can only be resolved by slowing down the filling process.

The graph of the extensional flow curves (see Figure 6) shows that the extensional viscosities of samples 1 and 2 (which performed well) are clearly lower then those of samples 3 and 5 (which did not perform well). The lower extensional

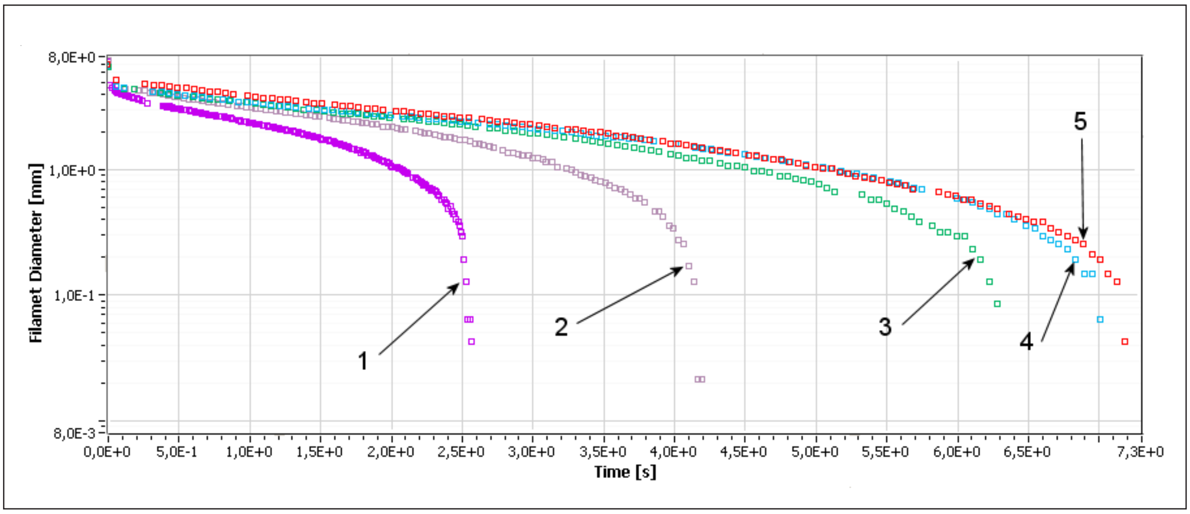


Figure 5: Filament diameter decay of shampoos in the CaBER experiment.

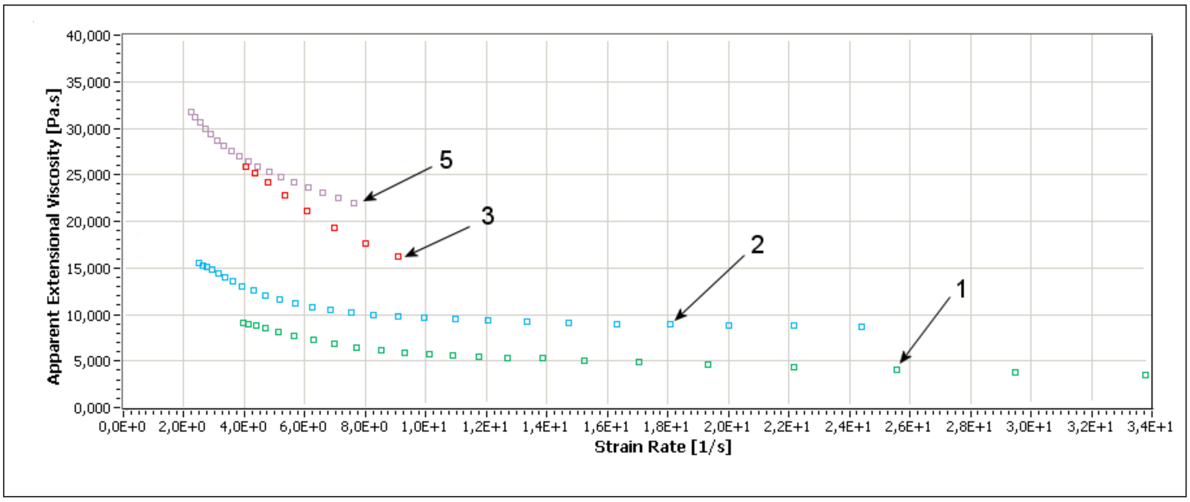


Figure 6: Extensional flow curves of shampoos 1-5.

viscosity leads to a higher strain rate and shorter break-up time (filament life time) in the CaBER experiment and in the filling equipment.

Conclusions

The HAAKE CaBER 1 extensional rheometer is capable of an easy-to-handle and quick way of distinguishing between different shampoos and of predicting filament lifetimes for production and quality control. Shampoos 3 - 5 will need to be reformulated to solve the serious filling problems. In this way it is possible to optimize the quality of the shampoos and the production process.

References

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