Flowability of Detergent Powder under Dry and Humid Conditions

Relevant for: Powder Rheology, Powder Shear Cell, Detergents, Tropical Climate

Detergent powder exposed to hot and humid conditions tends to form clumps which makes dosing difficult and reduces cleaning performance. The powder shear cell can assist you when checking new formulations.

1 Introduction

When detergent powder is exposed to hot and humid climate conditions its flowability can be reduced and its caking or clumping behavior increased. This can have a negative effect when dosing or on its cleaning performance since clumped powder tends to dissolve worse than its loose counterpart. In particular when residual detergent keeps present in form of white clumps after the washing, the caking of the powder was severe. Therefore, having a measurement method available to study caking and clumping of the detergent powder prior to dissolving in washing water is very valuable for evaluating different formulations.

In general, clumps are formed in humid environment when moisture accumulates on the surface of the grains. Two different processes may lead to clumping:

- If the powder is able to be dissolved in water, the surface layer dissolves and leads to sticky grains that form clumps and/or aggregates.
- If the powder is not soluble in water, the moisture accumulates between the grains and forms liquid bridges. Once evaporated surface tension pulls the grains together and they form loose aggregates.

Both of these modes are subsumed into the phenomenon of caking (also called time consolidation) and can be quantified either by caking tests or directly in the shear cell.

We show how the powder shear cell mounted on a modular compact rheometer (MCR) and connected to a humidity generator can assist you to check your formulation. Powder shear measurements before and after time consolidation of the powder exposed to different humidity levels at a temperature of 35 °C were carried out to determine the flowability and caking ability of the detergent powder. Three different relative humidity levels were chosen to simulate tropical humid (70 %rH), tropical dry (35 %rH) and very dry (7 %rH) climate. The results clearly show a reduced flowability and increased caking of the powder exposed to tropical humid climate. Hence, it is recommended to store detergent powder in a dry environment to avoid a loss of performance.

2 Experimental Setup and Sample

An air-bearing-based Modular Compact Rheometer (MCR) from Anton Paar equipped with a convection temperature device (CTD, humidity-ready), a humidity generator and a powder shear cell was used to run the measurements, investigating powder characteristics and caking of a commercially available detergent powder.

2.1 Influence of Humidity on Flowability of Detergent Powder

The sample was loaded into the powder shear cell which was placed within the CTD on the MCR and exposed to a defined relative humidity for 4 hours at 35 °C. Each preshearing step was accompanied by multiple shear-to-failure steps. The powder was exposed to preshear normal stresses of 3 kPa, 6 kPa, and 9 kPa. The accompanied failure tests (shear-to-failure) were performed at a lower compaction as defined in our RheoCompass™ template. The results are automatically analyzed and quantified in the software.

For more details on powder shear cell measurements please refer to the application report “Introduction to powder rheology”.

2.2 Influence of Humidity on Caking of Detergent Powder

In order to study the effect of humidity on time consolidation (caking), three different tests were carried out. First, the sample was presheared at 3 kPa. Then the sample was consolidated at 3 kPa at 35 °C for 16 hours at varying humidity conditions before a shear-to-failure test was carried out. The consolidation may take place inside the CTD chamber itself or in a climate cabinet to have the shear cell available for other measurements.

By comparing results before and after consolidation, the ability for caking can be determined.

3 Results

The results of the powder shear measurements are displayed in Mohr’s stress diagram. Figure 1 shows the Mohr circles for the preshear normal stresses of 3 kPa, 6 kPa, and 9 kPa at a relative humidity of 70 % and a temperature of 35 °C. The resulting three yield locus functions are clearly distinguishable.

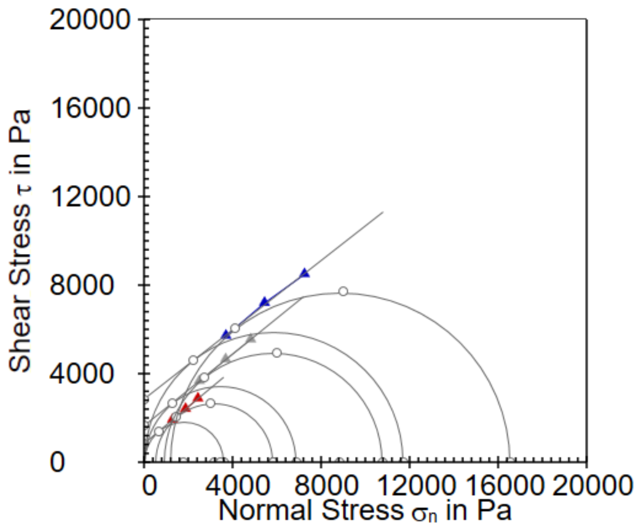

Figure 1: Mohr’s stress diagram of detergent exposed to 70 %rH and 35°C.

From the Mohr’s stress diagram, the coefficient of flowability ff_c can be evaluated from the major principal stress and the unconfined yield strength for each preshear normal stress. This step is also done automatically in the RheoCompass™ software. The flowability coefficient is presented in the ff_c diagram (Figure 2) where the unconfined yield strength is depicted over the major principle stress. This diagram includes the measurements for preshear normal stress of 3 kPa, 6 kPa, and 9 kPa.

The flowability of the detergent powder exposed to 7 %rH and 35 %rH over 4 hours is similar and classified as easy-flowing powder. The powder exposed to 70 %rH is classified as very cohesive. The influence of the humidity on the flowability of detergents is obvious.

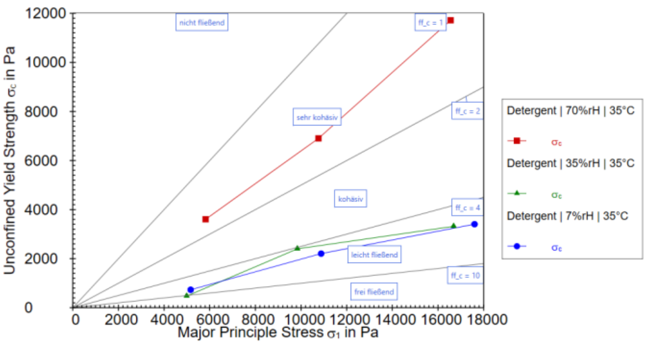

Figure 2: ff_c diagram showing flowability of a detergent exposed to three different relative humidity levels at 35 °C for 4 hours.

To investigate time consolidation of the detergent, the powder sample is exposed to the same environmental conditions as used in course of the shear measurements. During this time, the sample is consolidated by applying a normal stress. In this case, a rather small normal stress of 3 kPa was chosen to simulate storage conditions as arising when storing small amounts of detergent powder (non-industrial quantities).

Figure 3 shows the flowability of the detergent powder before and after consolidation. In case of 7 %rH and 35 %rH, the flowability even improved slightly after consolidation (i.e. lower unconfined yield strength). When humidity is high (70 %rH), the flowability changed drastically, from very cohesive to non-flowing.

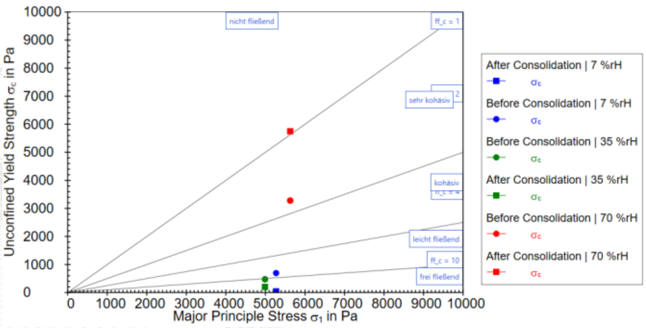

Figure 3: ff_c diagram showing the flowability of detergent powders exposed to different humidity levels and consolidated at those conditions for 16 h. High humidity reduces the flowability.

4 Conclusion

The powder shear cell in combination with the MCR, CTD, and humidity generator is a great tool to simulate different environmental conditions allowing to study their influence on flowability and caking behavior of detergent powder. The acquired knowledge can be directly applied to formulation to estimate and improve shelf life and resilience in the face of moist environmental conditions. Hence, this set up is a valuable analysis device when investigating new detergent formulations.

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