HIGH-PRESSURE INSTRUMENTS

FOAM AND INTERFACIAL ANALYSIS UNDER RESERVOIR CONDITIONS



KRÜSS

Advancing your Surface Science



Our solutions make knowledge your platform for yield maximization

OPTIMIZING FLOODING METHODS USING INTERFACIAL CHEMISTRY

Chemical flooding

By flooding with liquid mixtures, great quantities of oil can be obtained from reservoirs which no longer provide a yield with conventional recovery methods. The surfactants contained in the flooding mixture or produced *in situ* reduce the interfacial tension with respect to oil. This enables it to be mobilized and conveyed to the production well. It is therefore essential to know the interfacial tension under the pressure and temperature conditions of the reservoir.

Understanding the wetting behavior is equally important, because it controls fluid transport and the residual oil saturation in the reservoir rock. If the rock is poorly wetted by the liquid, then the mixture seeks a path along the largest pores and seeps through the rock. Only a small portion of the oil is then captured in spite of all the effort. Here, high-pressure measurements of the contact angle at the rock help to specifically improve wettability alteration and thus ensure a uniform liquid front.

Once the liquid reaches the pores, it is decisive that a change in the liquid phase occurs at the rock. If the oil prefers to adhere to the rock it will be impossible to mobilize it. Contact angle measurements with the appropriate liquids under high pressure show if the rock is rather wetted by the aqueous flooding mixture, as desired, or by the oil.

Foam-assisted gas flooding

Flooding methods for oil recovery with gases such as carbon dioxide or nitrogen can be assisted by foam which is either injected at the surface or formed in the reservoir. Foam improves the control of flow thanks to its increased viscosity. Even fingering and the gas override effect, whereby the gas flows above the oil-bearing strata due to its lower density, can be prevented by foam.

Such flooding methods place particularly high requirements on the nature of the foam. The foam must absorb as much gas as possible and withstand major deformation when flowing through porous rock. Moreover, the foam must remain stable for a long time to sustain the required effect throughout the whole process.

Intensive investigations in advance, which ideally reproduce the process conditions, are necessary to maximize the yield. Foam stability and bubble structure-analyses under high pressures and temperatures help to create effective mixtures for foam-assisted gas flooding.



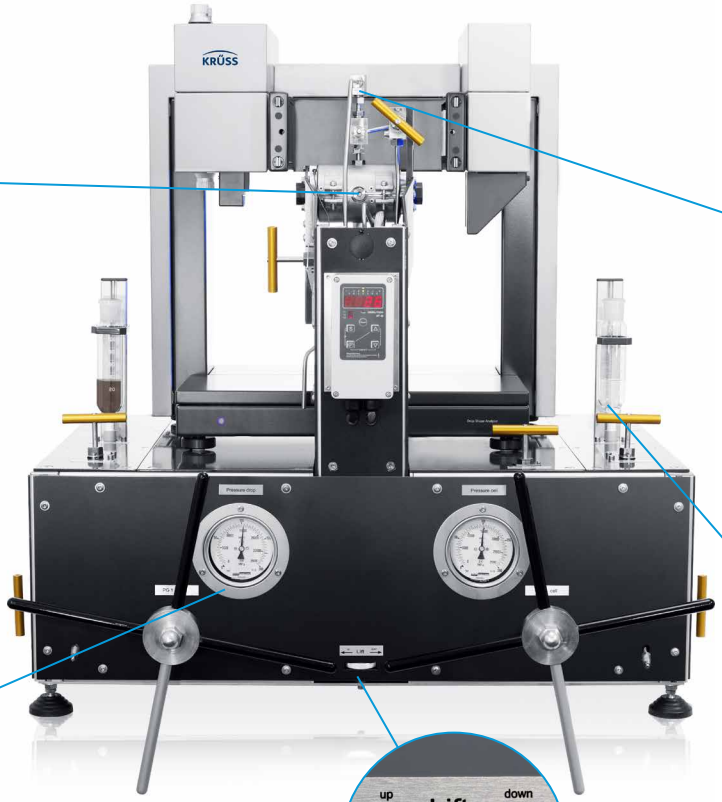
DROP SHAPE ANALYZER – DSA100HP

Samples can be moved while the pressure chamber is closed



Drop deposition above or below the sample





Either a liquid or a gas can be added as surrounding phase



Measurements under high pressure up to 1750 bar



Needle can be moved under high pressure







HIGH-PRESSURE INTERFACIAL TENSION AND WETTING ANALYSIS

- **Precision dosing and optical analysis of drops under high pressure**
- **Flexibly configurable for different reservoir and process conditions**

The Drop Shape Analyzer – DSA100HP is our high-quality solution for the precision measurement of contact angle as well as surface and interfacial tension under pressures up to 1750 bar. In order to carry out the measurement, the DSA100HP's high-resolution camera records video images of dosed drops through the pressure cell's viewing windows and these are then evaluated in real time.

The optimum configuration for different pressure ranges

The low to medium pressure range is covered by designs up to 40 and 690 bar, in each case at temperatures up to 200 °C. The new, heatable Mini Dosing System – MDS, which requires a sample volume as low as 2.5 mL and is distinguished by particularly easy handling, is available for these versions. The measuring range is substantially extended with a third variant up to 1750 bar at up to 250 °C. This will enable you to obtain meaningful data even under extreme reservoir conditions.

Flexible dosing options

All designs allow the sample and the dosing capillary to be positioned flexibly without opening the chamber, thus enabling several contact angles to be measured on one sample with very little effort. Good accessibility of all components makes filling and cleaning very easy.

Process conditions exactly simulated

The DSA100HP provides further options for accurately reproducing the conditions on site and for obtaining process-related results. An external gas connector is provided as standard, for example for measurements with liquid or supercritical CO_2. The surface tension and wettability results are therefore also relevant for gas flooding processes. Even oil with dissolved gas (live oil) can be connected and investigated.

The measuring cell is also available made from the corrosion-resistant alloy Hastelloy for carrying out measurements with salt water (brine) as found in reservoirs.

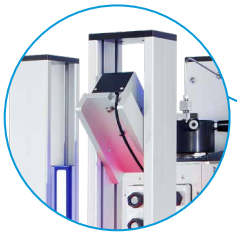
Measuring methods and options

- Contact angle measurement using a sessile drop
- Surface tension of a liquid in gas or interfacial tension between two liquids using a pendant drop
- Upside-down pendant drop measurement of an oil drop in water
- Measurements at pressures up to 1750 bar and temperatures between -10 and 250 °C

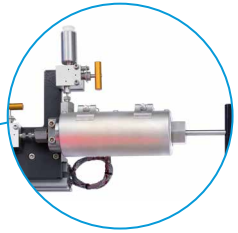


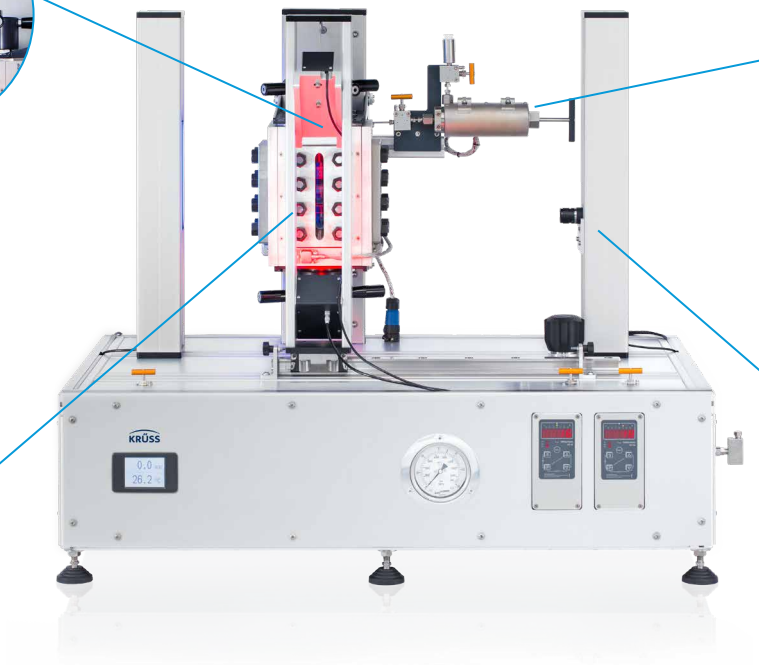
HIGH PRESSURE FOAM ANALYZER – HPFA

A high-resolution camera records the foam structure



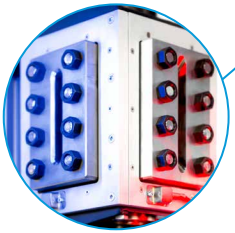
Liquids can be added while the analysis is running





A high-resolution camera captures the foam height





Foam is created reproducibly inside the high-pressure cell





OUR INNOVATIVE SOLUTION FOR FOAM ANALYSIS UNDER RESERVOIR CONDITIONS

- **Time-dependent analysis of foamability, foam stability and foam structure under high pressure**
- **Variable experimental procedures for process simulation**

Our High Pressure Foam Analyzer – HPFA is the world's only measuring instrument for simultaneously analyzing the amount and structure of liquid foams under high pressure. The instrument provides various options for investigating foam behavior under the real process conditions of foam-assisted flooding methods in oil production.

Measurement of foam height and structure with two cameras

While a gas flow is used to produce foam, two high-resolution cameras operating in parallel record the foam height and images of the foam lamellae. Supported by the real-time image evaluation of our ADVANCE software, the instrument determines the foamability and the foam decay. Within one and the same measurement, it also captures the change in bubble count per area and the absolute bubble size as well as its statistical distribution.



Simulation of extreme pressure conditions of oil reservoirs

The measuring cell works at pressures up to 350 bar and temperatures up to 120 °C, thus making it possible to observe the foam behavior under reservoir conditions. Sensors continuously transmit the pressure as well as the temperature to the ADVANCE software.

Flexible foaming conditions

Filters with different pore sizes are available for foaming to enable different lamella dimensions to be investigated. This option can be used to approach foaming conditions inside a particular reservoir with its characteristic rock porosity. Foaming can be carried out with air as well as carbon dioxide or nitrogen, which are frequently used for gas flooding.

Additional dosing during the experiment

How stable does aqueous foam remain when it comes into contact with a foam-inhibiting oil phase? The heatable Mini Dosing System – MDS of the HPFA enables this question to be answered exactly. As the analysis progresses, any required liquids can be dosed into the foam from above or into the liquid phase from below while maintaining the pressure. The effects on the foam can be observed live and based on the continuous data recording.

Measuring methods and options

- Measurement of foamability and foam stability based on the foam height and volume with respect to time
- Analysis of foam structure and its variation with respect to time based on the number, size and statistical size distribution of the foam bubbles
- Measurements at pressures up to 350 bar and temperatures up to 120 °C

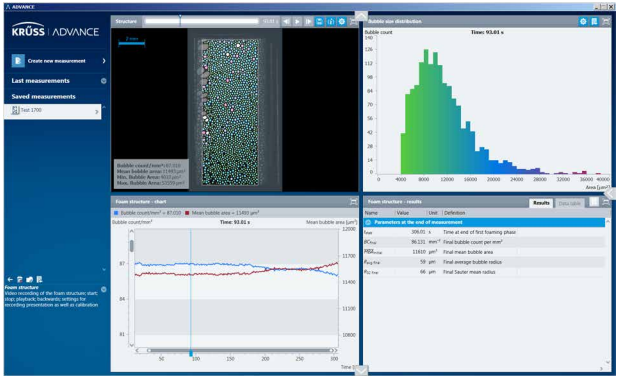
ADVANCE – OUR INTUITIVE SOFTWARE, OPTIMALLY DESIGNED FOR HIGH-PRESSURE ANALYSES

ADVANCE is our innovative software for instruments used in interfacial chemistry which sets new standards in intuitive operation. The relevant functions for each particular step are arranged in tiles which display all elements necessary in the context on the screen. By avoiding the use of menus and pop-ups, ADVANCE saves any unnecessary clicks and time-consuming searches for hidden elements.

ADVANCE for the Drop Shape Analyzer – DSA100HP

In the field of drop shape analysis, ADVANCE impresses with a powerful evaluation algorithm which can handle images that are difficult to analyze. This is very important for high-pressure applications, as disturbances of the drop shape often occur due to condensed gas, for example.

ADVANCE's automation options are also of great benefit, especially for long-term measurements. Flexibly selectable time segments enable fast initial dynamics as well as slow changes in a drop to be monitored. The associated image for each data point appears in the software's video tile with a single click.



Comprehensive foam structure evaluation for the HPFA

ADVANCE for the High Pressure Foam Analyzer – HPFA

Parallel real-time evaluation of foam height and foam structure is the heart of the ADVANCE configuration for the HPFA. By evaluating the image, ADVANCE detects the liquid/foam interface as well as the foam/gas boundary. Thus it is able to determine the absolute foam quantity and drainage with respect to time.

Simultaneously, ADVANCE evaluates a second camera image in order to detect the bubble structure and displays it clearly in a histogram. On completion of the measurement, the video images from both cameras and the histogram synchronized with the raw data points are shown so that each instant in time can be quickly reconstructed. Overall, the automatic evaluation provides a large number of meaningful result parameters:

- Total height, foam height and liquid height as well as volume for each measuring time
- Maximum foam density
- Half life of foam height and drainage
- Mean bubble size and standard deviation for each measuring time
- Mean Sauter radius for each measuring time
- Half life of the bubble count


You cannot see what happens
in the ground –
but you can come really close

ALWAYS CLOSE TO YOU

At KRÜSS, we combine technical know-how and scientific expertise with plenty of passion. That is why we not only produce high-quality measuring instruments for surface and interfacial chemistry – we offer a unique combination of product and scientific consulting. Our continuous know-how transfer ensures that not only we at KRÜSS keep pace with scientific developments, but also our customers.

In this way, we help you to optimize and make better use of your technologies. This has made us the global market leader in the field of surface and interfacial tension measurement. As a matter of course, we will gladly support you with further information as well. Feel free to ask us about publications, application cases, and helpful information about other KRÜSS products. We are always close to you.



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