Seismic Wave Tomography to Monitor Hydrate Formation and Production Experiments in LARS

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Abstract

The simulation of methane gas production from hydrates in laboratory experiments provides a cost and time efficient way to address a number of different scientific and technical questions to support the planning of expensive, time consuming, and laborious field tests. These studies under controlled conditions deliver input data for production modeling and can help to reduce risk and costs.

For production simulation the knowledge of hydrate distribution and habit is essential. For small samples X-ray and NMR tomography techniques are used to determine the hydrate distribution and to monitor hydrate decomposition during destabilization. Within the national German hydrate research project SUGAR the **la**rge **r**eservoir **s**imulator LARS was set up to perform hydrate production tests in a pilot plant scale. The hydrate-bearing sample in the temperature controlled pressure vessel of LARS has a length of 1300mm and a diameter of 460 mm, where the pressure vessel has an inner diameter of 600 mm, an outer diameter of 780 mm, and an overall height from the bottom to the top of the closure of 1800 mm. For a system of that size, X-ray and NMR tomography is not an option. Thus, we had installed an electrical resistivity tomography (ERT) with 375 electrodes in LARS to determine the initial hydrate distribution. The ERT worked quite reliable as long as only two phases, hydrate and water, are present besides the sediment. If gas is generated during the production or is injected into the sample, discrimination between gas and hydrate is not possible, because both are insulators.

To overcome this restriction we are now installing a seismic wave tomography (SWT) in LARS. The velocity contrasts between gas, water and hydrate saturated areas of the sample are high. A combination of ERT and SWT will provide a better saturation distribution for the different pore filling phases, hydrate, water, and gas. Besides the production simulation tests, the combination of ERT and SWT might also produce valuable data for the improvement of joint interpretation approaches of marine seismic and EM data.

The SWT-setup consist of the following components:

- a PC running the SWT sequence control routine,
- a high-voltage pulse generator, which is triggered by the sequence control routine,
- a high-voltage multiplexer providing the connection of the pulse generator to the seismic source selected by the sequence control system,
- a 24-channel transient recorder,
- a high density versatile multiplexer system providing the connections between the selected seismic receivers and the 24 channel transient recorder.

Although ultrasonic measurements are a standard method, the SWT for LARS is a challenging task.

1) The clearance between the inner wall of the pressure vessel and the sample is about 50 mm which restricts the size and therefore, the power of the seismic sources (96 sources along the outer sample wall).
2) In order to measure body wave velocities in lab samples, the wave length of the signal should be small compared to the sample size (as a rule: $\lambda \leq$ 1/5 of sample diameter). Because the velocity can reach values of up to 4500 m/s for hydrate saturated sands, the sources need to provide high signal power above 45 kHz.

3) Powerful seismic sources are needed, because hydrate-bearing sediments are known to possess high absorption. This is of particular importance, if besides water and hydrate a gas phase is present during production experiments. We have developed special seismic sources for LARS based on piezo-stack actuators, which provide a good compromise between size and power. These sources are driven by high power pulses (up to 1000V and 40A), which requires special insulation and shielding.

In this study the technical concept of the SWT under simulated in situ condition on hydrate-bearing sands in LARS together with first test measurements of the source-receiver system will be presented.