Poroelasticity of a Porous Underground Gas Storage System: Is there Material Fatigue?

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Abstract

Underground gas storages (UGS) play an important role in today's gas supply. Typical UGS sites are salt caverns, aquifers and former natural gas and oil reservoirs. The latter represent pore space gas storages. We study a potential UGS in the Molasse basin, southern Bavaria (Germany), consisting of a fine-grained reservoir sandstone underneath a marlstone seal as part of the interdisciplinary research project SUBI (Safety of underground storage during cyclic loading: Functionality, integrity and monitoring of storages and drillings).
UGS will have particular significance on "power to gas" projects, where wind or solar power is transferred to hydrogen and oxygen which can be used e.g. for methanation, i.e. the formation of artificial CH4 from the above mentioned hydrogen and carbon from decarbonisation processes. “Power to gas” usage of UGSs will lead to a higher frequency in depletion and refilling cycles and possibly faster material fatigue as is the case nowadays. Consequently, material fatigue of the UGS rocks is an issue of paramount importance for gas storage operators. We present here results of cyclic compressibility tests which are aimed to find out if and how the poroelastic parameters change with ongoing cyclic deformation.
We carried out a sequence of cyclic compressibility tests starting with a hydrostatic CPV (compressibility of pore volume) test for the determination of the bulk compressibility followed by an aging procedure (simulating 20 years of UGS depletion and inflation) and a second CPV test. Bulk compressibility data for the reservoir sandstone before and after the aging procedure are very much alike. Obviously, full elasticity is preserved over the simulated time of storage use. Bulk compressibility of the seal marlstone is about half a magnitude lower than for the reservoir sandstone. Simultaneously, the seal experienced double the volume strain during CPV01 and only 25% of it during CPV02 compared to the reservoir sandstone. Nevertheless, the bulk compressibility is almost unaffected by the change in volume strain and it seems that elasticity prevails also within the seal of the UGS. The aging procedure allows the determination of the compaction coefficient. The compaction coefficient of the relatively soft caprock is up to two magnitudes higher than the compaction coefficient of the reservoir sandstone. This observation reflects the strong mechanical discrepancy of both the lithologies. Simultaneously, the compaction coefficients do not change a lot for both lithologies: this is another hint for prevalence of elasticity over the entire testing process.
Compressibility tests as those presented here are an invaluable tool for the determination of the poroelasticity of an UGS. Although different in compressibility and compaction, the sandstone and the marlstone have one thing in common: a high reproducibility of the data which points to the dominant elasticity during the entire deformation and aging process. Nevertheless, further tests are necessary to verify our observations so far before they may be applied to the entire investigated reservoir-seal system.