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Thermo-mechanical modelling of cyclic gas storage applications in salt caverns

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Due to the growing importance of renewable energy sources it becomes more and more necessary to investigate energy storage potentials. One major way to store energy is the power-to-gas concept. Excessive electrical energy can be used either to produce hydrogen or methane by electrolysis or methanation or to compress air, respectively. Those produced gases can then be stored in artificial salt caverns, which are constructed in large salt formations by solution mining.
In combination with renewable energy sources, the power-to-gas concept is subjected to fluctuations. Compression and expansion of the storage gases lead to temperature differences within the salt rock. The variations can advance several metres into the host rock, influencing its material behaviour, inducing thermal stresses and altering the creep response.

To investigate the temperature influence on the cavern capacity, we have developed a numerical model to simulate the thermo-mechanical behaviour of salt caverns during cyclic gas storage. The model considers the thermodynamic behaviour of the stored gases as well as the heat transport and the temperature dependent material properties of the host rock. Therefore, we utilized well-known constitutive thermo-visco-plastic material models, implemented into the open source-scientific software OpenGeoSys. Both thermal and mechanical processes are solved using a finite element approach, connected via a staggered coupling scheme. The model allows the assessment of the structural safety as well as the convergence of the salt caverns.