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An Open-Source Simulator for Energy Storage in Heterogeneous Salt Caverns

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SAFEINCAVE: AN OPEN-SOURCE SIMULATOR FOR ENERGY STORAGE IN HETEROGENEOUS SALT CAVERNS

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Abstract

Utilization of salt caverns for underground gas storage (UGS), including hydrogen, is expected to increase in the coming years. This scaling up leads to cavern development in more heterogeneous geosystems, even close to the boundary of the salt rock deposits around the porous rock formations. These cases increase the chance of weakening the cavern stability, especially when operated under fast cycles. In face of these concerns, reliable numerical simulation of the mechanical response of heterogeneous salt caverns with complex geometries is key to ensure mechanical stability under different operational conditions. Furthermore, numerical simulations can aid in designing safe cavern abandonment strategies, a crucial phase with high societal concerns.

Although salt cavern simulation is necessary, building trust in the numerical results is a challenging task. The reliability of numerical results depends on many different aspects, such as the choice and calibration of appropriate constitutive models, the use of robust numerical schemes, appropriate domain discretization, initial and boundary conditions, etc. “SafeInCave” is an open-source simulator developed to address these aspects. It contains an efficient framework to design, test and calibrate constitutive models for salt rocks in triaxial tests. The current constitutive models include transient creep, reverse transient creep, and steady-state creep (dislocation and pressure solution). The constitutive models are also implemented in a robust 3D finite element simulator. The numerical formulation is specifically developed to (i) easily incorporate new constitutive models, and (ii) provide accurate results for tetrahedral meshes, which are able to efficiently represent complex cavern shapes and geological structures. Finally, a thermodynamic model for brine allows for cavern abandonment simulations. The capabilities and practical applications of SafeInCave are presented and discussed in this work.

Key words: Computer Software, Caverns for Gas Storage, Abandonment, Modeling, Model Calibration, Rock Mechanics