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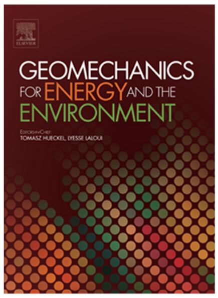

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A. Rouabhi, G. Hévin, A. Soubeyran, P. Labaune, F. Louvet

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A multiphase multicomponent modeling approach of underground salt cavern storage

A. Rouabhi[a,*], G. Hévin[b], A. Soubeyran[a], P. Labaune[a], F. Louvet[b]

[a]MINES ParisTech, PSL Research University, Centre de Géosciences, 35 rue St Honoré 77300 Fontainebleau, France
[b]Storengy, 12 rue Raoul Nordling 92274 Bois-Colombes, France

Abstract

In the current energy transition context, large-scale underground facilities, such as salt caverns, able to deliver high flow rates, represent the most promising viable massive energy storage system that can respond efficiently to the flexibility needs of the renewable energy.

In order to predict the performances of these facilities, while ensuring a high safety level over long time periods, the reservoir behavior must be studied by higher accuracy approaches. Based on a multiphase multicomponent approach, a cavern thermodynamic model, that can be used in field applications, is derived for this purpose. Particular attention is given to salt caverns where the stored fluid can be in contact with the brine. All the balance equations that govern the well that connects the cavern to the ground surface and the surrounding formation are presented. An illustrative example, showing the necessity of taking into account the thermo-mechanical aspects when considering the cavern thermodynamic behavior under cyclic loading conditions, is also discussed.

Keywords: Underground storage; Salt caverns; Multiphase multicomponent system; Balance equations; Viscoplasticity; Cyclic loading

1. Introduction

Over the last few years, the energy transition context has led to the emergence of several massive energy storage concepts aiming particularly at solving the uncontrollable intermittency problem that characterizes renewable energy based on wind, solar, or both resources. Among these concepts we may cite the CAES (Compressed Air Energy Storage) and the PtG (Power to Gas) concepts, both based on the excess electrical energy either from the renewable energy sources or through the efficient use of nuclear and fossil fuel. The CAES principle [1–4] consists in using compressed ambient air as a working fluid to be stored in underground storage reservoirs and expanded, when needed, in turbines to produce electricity. For better performances, the heat of compression can be stored in a thermal regenerator and recovered during expansion thus leading to an increase of the energy efficiency [5, 6]. The PtG concept [7–9] is a process where the excess power is converted into storable chemical energy carriers. Within this concept, one promising option is the production of hydrogen (H_2) and synthetic methane (CH_4) through an electrolysis-methanation process. The hybridization of the PtG concept with an oxy-fuel combustion process can lead to a closed loop technology since the generated oxygen (O_2) from the electrolysis phase, or a mixture of O_2 and recycled flue gas, can be stored and re-used to form the oxidizer for the combustion of methane in the energy retrieval phase. The resulting carbon dioxide (CO_2) from the oxy-fuel process can thereby be stored and subsequently used to feed the methanation process during the energy storage phase ([10], the on-going French project ANR FluidSTORY [11]).

All these processes require temporary large-scale reversible storage facilities for large amounts of fluids (air, CH_4, H_2, CO_2...). Currently, underground storage reservoirs seem to be the most promising low cost technologies. Two main categories of underground storage are in use today: porous media reservoirs where the working fluid is stored in the pore space, and rock caverns where the fluid is contained in excavated hard rock or solution-mined caverns. Obviously, although each category of storage has its own characteristics, some fundamental requirements, such as tightness, are common for both categories. In porous media, the sealing capacity against fluid leakage is provided by the geological reservoir structure whereas, in rock caverns, it is ensured by either the low host rock permeability in unlined caverns or by a suitable lining system for lined rock caverns. When the reservoir tightness is ensured, rock caverns behave like pressurized vessels, thereby allowing high deliverability flow rates as opposed to porous media where injection-widthdrawal rates are limited by the reservoir permeability. Consequently, they can better suit the flexibility needs of the renewable energy. The present study only deals with this storage mode and especially with solution-mined caverns.

The hydrocarbon underground storage in solution-mined

*Corresponding author
Email address: ahmed.rouabhi@mines-paristech.fr (A. Rouabhi)