PhD Thesis Carnot-Région Lorraine 2023

EXPERIMENTAL STUDY OF THE IMPACT OF THERMO-MECHANICAL STRESSES ON THE GAS PERMEABILITY OF ROCK SALT

Context and objectives of the thesis

At present, hydrogen is considered as a renewable energy source with promising prospects, which should be able to complement fossil fuels in the near future. The geological storage of gaseous hydrogen in salt caverns is considered today as the most economical and reliable solution, guaranteeing large available volumes, stability and long-term sealing. The principle of geological hydrogen storage is based on experience with natural gas (methane), commonly used to provide seasonal supply. While there were no notable incidents, the future use envisioned for H_2 storage could be a very different experience, especially given the high mobility of the H_2 molecule and the more frequent cycles of injection and gas withdrawal. These extreme operating conditions, which induce higher Thermo-Mechanical (TM) stresses on the salt caverns, could initiate the development of fractured zones and thus negatively impact the transport properties and therefore potentially cause leaks. In this context, a secure use of cavities for this clean and sustainable energy vector remains to be demonstrated. Thus, the objectives of the thesis are to:

i. characterize the impact of dynamic fatigue (mechanical and thermal), linked to cycling conditions, on rock salt permeability,

ii. estimate the contribution of different transport (diffusion, permeation) and deformation (damage, viscoplasticity, self-healing) mechanisms on H_2 leaks,

iii. determine the most appropriate rock salt formation for such a type of storage.

Methodology

The impact of mechanical and thermal dynamic fatigue on the damage and gas (nitrogen) permeability of rock salt will be studied in a triaxial compression cell by applying thermo-mechanical loading paths on cylindrical specimens (large dimensions taking into account of the large size of the salt crystals). High temperatures (up to 100°C) and stresses will be applied on the rock salt specimens and the associated deformations will be measured continuously. The porosity and cracks associated with the damage will be quantified initially and after testing by 3D X-ray tomography.

One of the major difficulties will be to accurately and continuously measure low gas flows, given the very low initial permeability of the salt. Another difficulty will consist in obtaining healthy salt samples, i.e., as close as possible to the initial state. It will therefore be a question of determining an optimal procedure to bring the cylindrical test specimens of rock salt back to their initial state by subjecting them to long periods under temperature and isotropic stresses, thus allowing the self-healing process (characteristic of salt) to operate. Different types of saline rocks will be studied in order to choose the most appropriate salt for hydrogen storage, i.e., the one whose mechanical and hydraulic properties will be the least affected by mechanical and thermal stresses.

Compétences scientifiques recherchées

Solid basis in continuum mechanics, rock mechanics, transfers in porous media, rock physics. Knowledge of geomaterials will be appreciated. The taste and interest for laboratory experiments are essential. Motivation and initiative, ability to work in a team.

Contract details

Duration: 3 years (October 1st, 2023 to September 31th, 2026)
Gross salary: 2080 € per month

Application file

Application deadline: **June 11th, 2023**

Documents to provide:

- Cover letter
- Curriculum vitae
- Copies of certificates of each university degree and Master's 1 and 2 scores
- Recommendation letter

Eligibility:

- All European and non-European citizens can apply
- Candidates must hold a Master's degree or equivalent
- Candidates whose first language is not French must have written and oral English skills

Supervision and contact

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