Masters degree internship

Investigation of micro-damage in salt-rock samples from the quantitative analysis of X-ray computed tomography 3D images

Start: February/March 2025
Duration: 6 months
Place: Laboratoire Navier (Ecole Nationale des Ponts et Chaussées - 77420 Champs-sur-Marne)
Supervisors: Adriana Quacquarelli (Navier, ENPC), Nina Du (Navier, ENPC – LMS, Ecole Polytechnique), Michel Bornert (Navier, ENPC), Alexandre Dimanov (LMS, Ecole Polytecnique)
Salary: 550 €/month

Context

Renewable hydrogen stands as a valuable alternative to fossil energy. The increase in hydrogen demand and production begs the question of its underground storage as a large-scale solution. In this context, large-scale engineered caverns in rock-salt geological formations seem to be a promising solution in terms of cost efficiency and safety in the long-term (Berest et al. 2019).

It is, therefore, necessary to assess the rock-salt tightness to hydrogen by analysing the mechanical response of rock-salt samples subjected to stress conditions comparable to the field conditions. In this framework, the proposed internship aims better to comprehend micro-damage and fracture propagation in synthetic salt-rock samples. It will be part of the RockStorHy project funded by the ANR, which seeks to analyse the mechanical behaviour of the salt-rock in the short and long term. The project is based on complementary experimental and numerical multiscale approaches to investigate its viscoplastic flow.

Objectives

Triaxial tests combined with X-ray Computer Tomography (XRCT) imaging have been performed at the Psiché beamline of Synchroton Soleil and in the lab tomograph of Laboratoire Navier. Wet and dry synthetic salt samples were prepared and tested by uniaxial and triaxial compression under different confining pressures and differential stresses representative of the conditions near caverns. Moreover, different loading velocities are experimented.

The main purpose of the project is to improve the characterization of the fracture evolution within salt samples and relate it to the brine content and loading conditions by exploring qualitatively and quantitatively the 3D images obtained by XRCT. The main objectives are:

1. Characterize the fracture pattern qualitatively.
2. Perform a local analysis of fracture propagation, using in particular digital volume correlation (DVC) technique.
3. Assess some quantitative evaluation of the salt mechanical behavior based on image analysis.

Salt-rock images are poorly-contrasted and cannot be analyzed with standard image correlation techniques; advanced image processing tools are therefore needed. The intern is expected to employ these tools and integrate the results obtained based on previous studies carried out on the topic (Bourcier et al. 2012, Gaye 2015, Du et al. 2025). It is expected that the quantitative use of the grey levels of the XRCT images will provide evaluations of crack openings with sub-voxel accuracy, as in (Chen et al. 2020).

Depending on the internship's progress, further experimental tests with different loading conditions might be performed on the lab tomograph for a more comprehensive analysis. In addition, tests on natural salt-rock samples are already planned and the intern might participate in them.

Skills required

- Master's degree or 3rd year of the engineering cycle with a background in mechanics, materials or geomechanics.
- Interest in image processing and advanced experimental techniques.
- Knowledge of programming languages (such as Python) is appreciated.

Contacts

Adriana Quacquarelli `adriana.quacquarelli@enpc.fr`
Michel Bornert `michel.bornert@enpc.fr`

References

Berest, Pierre et al. (Jan. 2019). "Review and analysis of historical leakages from storage salt caverns wells". In: *Oil & Gas Science and Technology* 74, p. 27. DOI: 10.2516/ogst/2018093.

Bourcier, Mathieu et al. (Jan. 2012). "Full field investigation of salt deformation at room temperature: Cooperation of crystal plasticity and grain sliding". In: *Mechanical Behavior of Salt VII - Proceedings of the 7th Conference on the Mechanical Behavior of Salt*.

Chen, Y. et al. (2020). "3D Detection and Quantitative Characterization of Cracks in a Ceramic Matrix Composite Tube Using X-Ray Computed Tomography". In: *Experimental Mechanics* 60.3, pp. 409–424.

Du, Nina et al. (2025). "Deformation, cracking and healing mechanisms in rock salt: a microscale study". In: *Proceedings of IS Grenoble*. in press.

Gaye, Ababacar (Mar. 2015). "Micromechanics of halite investigated by 2D and 3D multiscale full field measurements". PhD thesis.