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Integrated Fracture and Thermo-Hydro-Mechanical (THM) Simulators to Investigate Near-Wellbore Stress Changes in Underground Hydrogen Storage

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Introduction

Problem Statement:
Renewable energy has seasonal dependency; Storing H₂ in aquifer can be the solution

Most study on H₂ modeling considers hydrodynamics, few consider geomechanics, but none consider the thermal stresses

Reservoir Modeling is essential for safety of Underground Hydrogen Storage (UHS)

Common geomechanics software only show rock failure potential, without indicating where the hydrogen goes in case of fractures

Objectives:
1. Evaluate the impact of thermal stresses on cyclical UHS
2. Quantify the extent of rock failure or fracture in the near-wellbore region
3. Determine optimal injection controls to maintain storage integrity

Methodology: Numerical Simulation of Saline Aquifers
We used numerical simulator that integrates thermal, flow, geomechanics, and fracture processes. Initial pressure gradient is at 10 MPa/km, and geothermal gradient at 30°C/km. The reservoir condition is 25MPa and 90°C.

Results & Discussions

Case 1: Isothermal Case
Injection Rate = 18 m³/s
No Fracture even after 4th Cycle

Figure 3 – Isothermal model did not find any rock failure in base reservoir condition but high injection rate.

Case 2: Thermo-Hydro-Mechanical + Fracture Case
Injection Rate = 18 m³/s
Fracture found after 7 days of 1st cycle injection

Figure 4 – Small fracture found around the wellbore, indicating the importance of thermal integration

Case 3: Findings in Low Permeability Reservoir

Figure 6 – Very small fracture is predicted in isothermal model, and H₂ is contained in storage layer after 4 cycle

Figure 7 – In thermal model, Fracture is generated after 2 days of injection. H₂ tries to escape upwards.

Conclusion

Coupled THM and fracture simulation identify UHS risks in saline aquifers, providing novel insights towards hydrogen injection performance:

1. The study predicts that an increase in the number of injection and extraction cycles may heighten UHS integrity risks due to changes in thermoporoelastic stresses
   • Higher fracture risks are associated with conditions of low permeability, low fracture gradients, low compressibility, and low Poisson's ratio.

2. The model predicts the extent of fractures in near-wellbore region, and suggests that the gas can escape storage formation if fracturing occurs.

3. Lower temperature difference (<65°C) and lower rate of H₂ injection (<18 sm³/d) would reduce the risks of fracturing in UHS.

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References
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