Danish Offshore Technology Centre
Technology Conference 2024

Assessing Fault Reactivation and Induced Seismicity During CO2 Injection in Depleted Chalk Fields

M.R. Hajiabadi, F. Amour, B. Hosseinzadeh, H.M. Nick
Danish Offshore Technology Centre, DTU Offshore, Technical University of Denmark, Lyngby, Denmark

In the Danish North Sea, more than ten depleted chalk fields offer significant potential for CO2 storage. Research on CO2 storage in chalk has primarily focused on core flooding experiments, which indicate minimal mechanical changes during continuous CO2 injection. While these results are promising, a lack of field-scale simulation studies leaves key uncertainties regarding flow, mechanical, chemical, and thermal responses in chalk storage sites. Notably, most chalk reservoirs have undergone substantial deformation, up to 5–10 meters, during production. Consequently, stress redistribution at the end of production plays a crucial role in fault reactivation during the CO2 injection phase.

This study, part of the Bifrost project funded by the Danish Energy Technology Development and Demonstration Programme (EUDP), investigates induced seismicity by evaluating potential fault reactivation in the Harald East chalk field, a depleted gas reservoir in the Danish North Sea. Two models are employed in this research. The first model, built in Petrel, spans 11 × 9 km and is 4 km thick, covering the overburden, sideburden, underburden, and the reservoir from the seafloor to the base chalk unconformity. The second model, created based on the Petrel model, is used in Abaqus.

In the Petrel model, Thermal-Hydraulic-Mechanical (THM) simulations are performed using a thermal flow simulator (Intersect) coupled with a geomechanics simulator (Visage), with history matching based on over 30 years of production data, 4D seismic data, and platform subsidence measurements. The flow and mechanical simulators are calibrated using PVT and triaxial test data from North Sea fluid and rock samples. Slip tendency analysis conducted at the end of the production phase using the Petrel model indicates no fault reactivation, a result confirmed by 4D seismic data. Returning to virgin reservoir pressure during the injection phase, the Petrel model shows a very low risk of fault reactivation.

Since the Petrel model lacks a discrete fracture model, Abaqus is used to quantify seismic events during the injection phase more accurately. The Abaqus model incorporates a previously developed constitutive model for chalk, and a frictional model is applied to the fault. A comparison of the results from both models confirms the validity of the Abaqus model. Various injection phase scenarios are explored to assess the risk of significant seismic events.