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Hydro-mechanical simulations of well abandonment at the Ketzin pilot site for CO_2 storage verify wellbore system integrity

Victoria Unger and Thomas Kempka
GFZ German Research Centre for Geosciences, Hydrogeology, Potsdam, Germany (kempka@gfz-potsdam.de)

In geological underground utilisation, operating and abandoned wells have been identified as a main potential leakage pathways for reservoir fluids. In the scope of the well abandonment procedure currently carried out at the Ketzin pilot site for CO_2 storage in Germany, a hydro-mechanical model was built to carry out a coupled analysis of the integrity in the entire wellbore system. The main aim of the present study was to assess the impacts of stress changes associated with CO_2 injection as well as the cement backfill undertaken in the scope of well abandonment.

A numerical model comprising cement sheaths, steel casings, tubing, multiple packers and wellbore annuli was implemented to enable a detailed representation of the entire wellbore system. The numerical model grid has a horizontal discretisation of 5 m x 5 m to focus on near wellbore effects, whereby element sizes increase with increasing distance from the wellbore. Vertical grid discretisation uses a tartan grid type over the entire model thickness of 1,500 m to ensure a sufficient discretisation of all wellbore system elements as well as of the reservoir unit. The total number of elements amounts to 210,672.

Mechanical model parameters were taken from geological, drilling, logging and laboratory test data based on Ketzin pilot site-specific information as well as related literature (Kempka et al., 2014). The coupled calculations were performed using an elasto-plastic constitutive law, whereby an initial simulation run ensured a static mechanical equilibrium to represent the initial state before the start of CO_2 injection. Thereto, gravitational load of the overburden rocks and pore pressure distribution following available well logs were integrated for initial model parameterisation including a normal faulting stress regime defined by a horizontal to vertical total stress ratio of 0.85.

A correction accounting for the temperature and pressure dependent CO_2 density was carried out in advance of each simulation time step and verified by a comparison of calculated and observed bottomhole pressures for the operational phase. Well abandonment was simulated by stepwise filling of the wellbore with Schlumberger Evercrete and Class G cements considering the specific mechanical cement properties as a function of time to account for stress changes and displacements in the wellbore system and its surrounding.

Our simulation results indicate, that taking into account available site-specific data, failure of the wellbore system is unlikely to occur during site operation and subsequent abandonment. The implemented hydro-mechanical model can be consequently applied for investigation of different hypothetical scenarios including varying stress regimes, low-quality cementation jobs as well as casing corrosion. Furthermore, coupling with hydro-chemical simulations would allow for a long-term assessment of wellbore integrity and reservoir fluid leakage.

Kempka, T., Klapperer, S., Norden, B. Coupled hydro-mechanical simulations demonstrate system integrity at the Ketzin pilot site for CO_2 storage, Germany (2014) Rock Engineering and Rock Mechanics: Structures in and on Rock Masses - Proceedings of EUROCK 2014, ISRM European Regional Symposium, pp. 1317-1322.