Cement sheath bond integrity for CO_2 injection wells under periodic pressure and thermal loading

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Abstract

Periodic injection at CO_2 storage sites may result from intermittent transport by ships, planned or unplanned shutdowns for maintenance or pressure management, or upstream issues in the capture and transport chain. Hence, both new and repurposed CO_2 injection wells must be able to undergo conditions of periodic injection without sustaining damage leading to a loss of storage integrity. The associated thermal loading is a particular concern due to the potential for a CO_2-formation temperature difference and Joule-Thomson cooling in the near-well region. The influence of the latter may be exacerbated for CO_2 injection into depleted oil and gas fields due to their lower initial reservoir pressure. This work presents a numerical investigation of CO_2 injection well integrity with a particular focus on the degradation of cement sheath bonding with the casing and rock formation. The cement sheath and formation are treated as thermo-poroelastic materials subject to coupled thermo-hydro-mechanical behaviour. Bonding of the composite well structure at the casing-cement and cement-formation interfaces is handled within the finite element formulation using a cohesive zone model to handle mixed mode failure. Simulation scenarios are considered in relation to reservoir conditions, key material properties, period and amplitude of the applied hydro-thermal loads, and range of pre-existing defects ascribed to new and repurposed wells. While most simulations are performed in two dimensions under the assumption of plane strain, a three dimensional case is further considered to study both the azimuthal and axial extents of debonding. This is regarded as a critical extension of the work since it is otherwise difficult to relate damage in two dimensions with storage integrity risk. Results are predominantly compared on the basis of developed stresses and size of debonding, leading to conclusions regarding the system properties of greatest importance for injection well damage evolution and subsequent risk to CO_2 storage integrity.

Keywords: CO_2 storage; injection well integrity; periodic loading; coupled THM modelling; sensitivity analysis.