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Dynamic simulation of CO_2 injection wells

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Abstract

For CO_2 transport, pipelines are often cited as the most efficient alternative. However, CO_2 transport by ship is being considered for CO_2 sources close to the coast and far from an offshore storage site. In the early phases of CCS deployment, transported CO_2 quantities will be small, which makes ships the most cost-efficient means of transport. Ship transport will also be flexible in the sense that new sources can easily be added. Irrespective of means of transport, the CO_2 must flow through an injection well before it reaches the geological reservoir. The transport-storage interface constitutes one of the main challenges for transport of CO_2. Possible processing at the injection site, well-flow dynamics [2], well integrity [1] and the response of the CO_2 storage reservoir need to be described. This requires good knowledge of the relevant CO_2-rich fluid properties, as well as the flow in the well and coupling between well and near-well flow, the interaction of brine and CO_2, etc. [5].

Commercial simulators for wells and pipelines are mainly validated for the flow of oil and natural gas, with extensions existing for pure CO_2 [3]. In a CCS context, it is necessary also to consider impurities, since pure CO_2 may not be optimal from a whole-chain perspective. Small amounts of impurities are more challenging to simulate than large amounts, due to the resulting narrow phase envelope. CO_2-brine mixtures constitute a further challenge for the simulation of CO_2 injection wells, since brine may flow back from the reservoir into the well during shut-in or blow-out. The flow model then needs to be able to handle two liquid phases, one CO_2-rich and one brine-rich, and the two-way coupling between well and near-well flow.

In [4] we considered single- and two-phase flow during blow-out and shut-in in vertical CO_2-injection wells. In [1] we studied the heat transfer through the different materials surrounding the vertical pipe, and the resulting thermal stresses. For intermittent injection scenarios for direct offshore ship offloading, we found that high thermal stresses could occur. Hence, either a continuous injection scheme should be adopted, or suitable well materials should be chosen.

Even though normal operation may be virtually steady-state, dynamic situations will occur during shut-in, start-up, changes in the operating conditions or different undesired scenarios such as blow-out. The dynamics of the well flow is influenced by the response of the surrounding reservoir. This needs to be taken into account by applying appropriate boundary conditions at the wellbore perforation. Often the boundary conditions are formulated assuming a constant

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far-field reservoir pressure and permeability. This likely constitutes too large a simplification. Hence, in this work, we estimate the varying reservoir pressure and permeability by solving a near-well flow model which is bi-directionally coupled to the flow model of the well. The paper will discuss the effect of downhole boundary conditions, and point out situations where the reservoir dynamics will affect the well flow.

In particular, under some conditions, the brine in the reservoir may flow back into the well. This has practical consequences with respect to e.g. corrosion. In order to describe this phenomenon, we consider a flow model having two separate liquid phases, one CO_2-rich and one brine-rich. This will allow us to map out the circumstances under which backflow may occur for realistic well geometries.

Keywords: CO_2 capture and storage (CCS); Fluid dynamics; thermodynamics; carbon dioxide; well; reservoir.

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