Numerical and Experimental Investigation of CO_2 Hydrates on Injectivity Decline during CCS in Depleted Gas Fields

Rouhi Farajzadeh[1, 2], John Riaño Castañeda[2], Mahnaz Aghajanloo[2], Siavash Kahrobaei[1]

[1]Shell
[2]TU Delft

Abstract

The increasing levels of carbon dioxide (CO2) emissions in the atmosphere are significantly contributing to climate change. One approach to mitigate this issue is through Carbon Capture and Storage (CCS) techniques, which involve storing CO2 emissions underground. Depleted reservoirs are a potential option for subsurface CO2 storage. However, a challenge arises due to the disparity between injection pressure and reservoir pressure.

When CO2 is injected into the reservoir, it undergoes expansion and cooling (known as the Joule-Thomson cooling effect), potentially leading to the risk of CO2 hydrate formation when it interacts with connate water. CO2 hydrates pose a considerable threat to the success of CCS projects, as they can decrease injectivity near the wellbore, resulting in technical complications and increased costs. Thus, a thorough understanding of CO2 hydrate formation is imperative for the planning of robust and sustainable CCS initiatives. This study aims to elucidate the specific conditions under which CO2 hydrates are formed in a porous media and to assess their impact on injectivity decline. The investigation begins with a core flooding experiment designed to delve into the physical processes involved in CO2 hydrate formation and dissociation. It also explores potential methods for prevention, mitigation and remediation.

Subsequently, an empirical numerical reservoir simulator is developed to model the formation and dissociation of CO2 hydrates within the reservoir. The empirical model facilitates a sensitivity analysis of the parameters that influence hydrate formation and allows for the assessment of the efficacy of prevention techniques examined in the laboratory setting. The core flooding experiment helped to establish that hydrate formation is contingent upon specific pressure and temperature parameters within the hydrate stability zone. The experiment also delved into the impact of water saturation, connate water salinity, and the use of thermodynamic hydrate inhibitors (THIs) on the hydrate formation process. Furthermore, the experimental procedure facilitated the testing of prevention and remediation techniques after hydrate formation, including thermal stimulation and THIs injection. The empirical model, enabled a sensitivity analysis to identify the main parameters that affect hydrate formation. Additionally, the model investigated the resulting reduction in permeability, which ultimately led to diminished injectivity and increased injection pressure due to hydrate formation. Ultimately, both experimental and numerical approaches showed that the formation of hydrates leads to a reduction in permeability, thereby diminishing injectivity and elevating injection pressure.