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Visualizing the Effect of Gravity on Hydrogen Redistribution at Pore Scale

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Hydrogen is considered a low-carbon fuel that can potentially contribute to the large-scale decarbonization of different sectors, including power generation, heating, transportation, and industry. Blending hydrogen into national gas distribution networks can also help decarbonize distributed carbon emissions from domestic consumers where carbon capture is not feasible. More pilot projects worldwide, such as H100 Fife and HYDeploy2 in the UK and HyGrid in Long Island, US [1–3], are showcasing the use of hydrogen in the national gas networks. The reliable and robust operation of a gas network at the national scale (12 to 51TWh of hydrogen in the case of the UK national gas network [4]) would critically require safe and efficient large-scale hydrogen storage. As an example, to meet the UK's seasonal demand and production variations from intermittent renewable energies, 0.37-1.58 billion cubic meters of hydrogen storage capacity is required which represents 25-105% of the current UK strategic natural gas storage capacity [5]. This means large-scale repurposing of current storage sites (both salt caverns and depleted gas reservoirs) and the development of new sites.
To unlock the large-scale storage capacity of depleted gas reservoirs and saline aquifers for efficient hydrogen storage, understanding the flow and trapping mechanisms of hydrogen at the pore scale in contact with resident fluids is essential. To achieve this, a set of experiments is designed to explore the fluid distribution in cyclic fluid displacements representative of seasonal storage and production of hydrogen in subsurface reservoirs. These cyclic flow experiments are performed in a sandstone core and the fluid distribution at the pore scale is imaged by an X-ray micro-computed tomography (micro-CT) rig with a cubic voxel size of 3x3x3 microns. To achieve the highest imaging resolution with our in-house testing rig, a core sample size of 5mm diameter and 10mm length is selected. The outlet pressure is maintained by the receiving pump at 7.0 MPa. The fluids are injected through the core at a constant flow rate of 5 mL/hr to ensure capillary-dominated flow. Potassium iodide (KI) salt is dissolved as a dopant in the brine to provide effective contrast between the brine, hydrogen, and rock sections of the images. To ensure gravity-stable fronts, hydrogen is injected from the top and brine from the bottom of the core holder. The alternate injection of hydrogen and brine is then performed until no significant change in saturations is observed along the sample. After gas injection an average hydrogen saturation of 32% is observed in the core sample, however, about 6% fluctuation in saturations is observed. The core is then isolated for 30 days, and the imaging experiment was repeated. The amount of the displaced hydrogen by buoyancy effect and its distributions is then discussed. This provides insight into hydrogen displacement by gravity forces. Ongoing studies are investigating the trapping of hydrogen at similar flow conditions at the pore and core scale.

Participation

In-Person

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