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Numerical simulation of depleted and cushion gases impacts on hydrogen storage in a depleted gas reservoir

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Depleted gas reservoirs have large storage capacity, pre-proved containment security, in-place depleted gas, and well-established surface infrastructures, thus are viewed as the most feasible hydrogen storage space. However, the impacts of depletion time, volume ratio ($VR_{H_2:CH_4/CO_2}$) of hydrogen (H_2), depleted gas (mainly CH_4) and cushion gas (e.g., CO_2), and injection/withdrawal mode on hydrogen storage performance have not been systematically studied. Therefore, we examined these impacts using a numerical simulation method. The results demonstrate that: 1) As the $VR_{H_2:CH_4}$ decreases from 100% : 0 to 50% : 50%, both H_2 withdrawal factor (W_{F-H_2}) and purity (W_{P-H_2}) firstly increase and then decrease; during the 1^{st} withdrawal cycle, the highest W_{F-H_2} is 42% and the smallest W_{P-H_2} is 51%, both of which occur at the $VR_{H_2:CH_4}$ = 60% : 40%. 2) In case of CO_2 as cushion gas, W_{F-H_2} and W_{P-H_2} are decrease as the $VR_{H_2:CO_2}$ increases from 50% : 50% to 25% : 75%; during the 1^{st} withdrawal cycle, the highest W_{F-H_2} is 38% and the smallest W_{P-H_2} is 50%, both of which occur at the $VR_{H_2:CO_2}$ = 25% : 75%. 3) A smaller H_2 withdrawal rate (W_{R-H_2}) results in a lower W_{F-H_2}, but a higher W_{P-H_2}, e.g., at the $VR_{H_2:CH_4}$ = 60% : 40%, W_{F-H_2} and W_{P-H_2} are 42% and 51% at W_{R-H_2} = 100×10^4 Sm^3/day, respectively, while they become 31% and 64%, respectively, at W_{R-H_2} = 50×10^4 Sm^3/day. These simulation results indicate that cushion gas injection is beneficial to reducing hydrogen loss, and depleted gas can be used as cushion gas. Depletion time and the ratio of hydrogen, depleted and cushion gas have significant influence on hydrogen storage performance. These insights provide important guidance for industrial hydrogen storage in depleted gas reservoirs.

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