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Numerical Analysis of CO_2 Storage as Clathrates in Depleted Natural Gas Hydrate Formation

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Abstract : Holding CO_2 at massive scale in the enclathrated solid matter called hydrate can be perceived as one of the most reliable methods for CO_2 sequestration to take greenhouse gases emission control measures and global warming preventive actions. In this study, a dynamically coupled mass and heat transfer mathematical model is developed which elaborates the unsteady behavior of CO_2 flowing into a porous medium and converting itself into hydrates. The combined numerical model solution by implicit finite difference method is explained and through coupling the mass, momentum and heat conservation relations, an integrated model can be established to analyze the CO_2 hydrate growth within P-T equilibrium conditions. CO_2 phase transition, effect of hydrate nucleation by exothermic heat release and variations of thermo-physical properties has been studied during hydrate nucleation. The results illustrate that formation pressure distribution becomes stable at the early stage of hydrate nucleation process and always remains stable afterward, but formation temperature is unable to keep stable and varies during CO_2 injection and hydrate nucleation process. Initially, the temperature drops due to cold high-pressure CO_2 injection since when the massive hydrate growth triggers and temperature increases under the influence of exothermic heat evolution. Intermittently, it surpasses the initial formation temperature before CO_2 injection initiates. The hydrate growth rate increases by increasing injection pressure in the long formation and it also expands overall hydrate covered length in the same induction period. The results also show that the injection pressure conditions and hydrate growth rate affect other parameters like CO_2 velocity, CO_2 permeability, CO_2 density, CO_2 and H_2O saturation inside the porous medium. In order to enhance the hydrate growth rate and expand hydrate covered length, the injection temperature is reduced, but it did not give satisfactory outcomes. Hence, CO_2 injection in vacated natural gas hydrate porous sediment may form hydrate under low temperature and high-pressure conditions, but it seems very challenging on a huge scale in lengthy formations.

Keywords : CO_2 hydrates, CO_2 injection, CO_2 Phase transition, CO_2 sequestration
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