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Numerical Simulation of Cyclic Gas Injection Recovery Processes Applied to Unconventional Reservoirs Using Advanced Hybrid Fracture Models, Advanced Compositional Phase Behavior, State of the Art Diffusion Calculations, and Specialized Flow Properties

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ABSTRACT

The gas huff-n-puff process has been proposed as a recovery method in extremely low permeability, and heavily fractured unconventional oil and condensate gas reservoirs. This paper presents numerical simulations of this process utilizing advanced techniques in several areas: (1) the representation of complex fractures (2) compositional phase behavior that reflects the ultra-small pore sizes of unconventional rocks (3) state-of-the-art molecular diffusion calculations (4) Non-Darcy flow specifically developed for unconventional reservoirs. Results are compared to simulations that do not have these features. Previously published simulation studies have focused on the modeling of a segment of a horizontal well with simple regularly spaced vertical planar hydraulic fractures. In some cases, natural fractures with regular spacing and properties were also modeled. Additionally, complex phase behavior and flow properties that are special properties of unconventional reservoirs have been largely ignored. In this study, we stochastically generate for the whole length of a horizontal well a complex system of hydraulic and natural fractures, represented by a fine unstructured grid. We compare simulations utilized a simplified representation of this geological model with those incorporating geologic complexity by using a detailed unstructured grid representation of major hydraulic and natural fractures and a dual continuum model with up-scaled properties to represent natural fractures. The dual continuum model includes sub-gridding of the matrix blocks to capture transient effects. We determine the recovery with different injection gases under various production and injection scenarios varying such aspects as injection and production pressures, the length of injection and production periods, and soak time. Additionally, we compare our base case results with ones incorporating the effects of capillary pressure on phase equilibrium, multi-component adsorption effects on phase equilibrium and fluid flow, molecular diffusion, Knudsen diffusion, Forchheimer flow, and stress effects on fracture conductivity. The conditions under which these effects are important are identified. A complex molecular diffusion model is used that includes cross-diffusion terms and diffusive mass transfer.