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Integrated Compositional Simulation and Optimization for Gas Mobility Control Techniques during CO₂ Sequestration in Cranfield

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CO₂ sequestration in subsurface often suffers from poor volumetric sweep efficiency due to low gas viscosity, low gas density, and formation heterogeneity. This study aims to investigate CO₂ mobility control techniques of Water Alternating Gas (WAG) and Surfactant (or Nanoparticle) Alternating Gas (SAG) to increase CO₂ storage capacity in Cranfield Field, Mississippi via field-scale simulations and characterize key parameters critical to long-term CO₂ storage success through optimizations.

A parallel compositional simulator (IPARS) is used to accurately capture the underlying physical processes, with a field scale numerical model, over the desired time-span. A hysteretic relative permeability model enables modeling local capillary trapping. Foam-assisted CO₂ mobility control technique is examined with an implicit texture foam model to investigate the eminent level of CO₂ capillary trapping. A multipoint flux mixed finite element (MFMFE) method is used for spatial discretization of the compositional flow model. It can handle complex reservoir geometries using general distorted hexahedral grid elements, as well as satisfy local mass conservation and compute accurate phase fluxes. The WAG and foam injection process are further optimized for injection bottom hole pressure, number of cycles, length of the cycles, and foam properties via GA (genetic algorithm) in UT optimization toolbox.

Field scale simulations indicate that CO₂ storage volume increases by 15% and 24% compared to continuous CO₂ injection- during WAG and foam processes, respectively. During SAG process, foam is generated in the high permeability streaks and upper layers with higher CO₂ flow rates and diverts the CO₂ flow into low permeability regions and bottom layers, leading to more efficient areal and vertical sweep efficiency. The optimized foam process saved 60% water and surfactant consumption comparing to the base case foam process while achieving same CO₂ storage volume.

References

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