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Parallel numerical simulation analysis of the stress evolution within the full synthetic field model during CO2 geological storage

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The mechanical analysis and stability assessment of reservoir-caprock systems are critical considerations for the successful industrial implementation of CO2 geological storage. Injecting CO2 into the formation can cause fluid pressure accumulation, altering the effective stress field and subsequently leading to potential geological risks. Stress changes due to CO2 injection can activate faults, induce seismicity, and ground motion. However, the influence of stress change is not limited to the reservoir alone but extends to the broader subsurface formations including the overlying caprock, underlying basement, and the surrounding strata.

In this study, a full synthetic field model incorporating the reservoir, caprock, basement, and surrounding formation was established. A finite element grid was generated based on the existing corner point grid of the target reservoir. Using parallel computing, numerical simulations of coupled flow and geomechanics were conducted on a million-grid scale model to analyze the variations in effective stress during CO2 injection and storage. The simulation results indicate that during the injection stage, fluid pressure and shear stress gradually increase with time, while the average effective stress decreases, indicating a shift towards the failure envelope. After the cessation of injection, the stress state reverses but remains on the left side of the initial stress state. Fluid pressure and shear stress are higher than the pre-injection equilibrium values, while the average effective stress is lower. Increasing the number of CPU cores significantly reduces the computation time of the numerical simulations. However, beyond a certain number of cores, the overall parallel computation time increases due to increased communication burden among processors. As the size of the solving model increases, the acceleration ratio and parallel efficiency increase under the same number of processors.

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