透過有限元素法耦合熱水力化模型進行二氧化碳注入之建模

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摘要

地質二氧化碳封存已經被證實可以緩解溫室氣體排放。大量二氧化碳注入地層涉及溫壓改變、化學反應、溶質傳輸與岩石機械回饋等交互作用；此為一熱水力化(THMC)之耦合過程。在井孔區域周圍進行二氧化碳注入的數值模型可以提供如岩性、力與壓力改變等此類的資訊，可以幫助預測注入後之狀態與滲漏風險。在本文章中提出一個以有限元素方法為基礎的完全耦合熱水力化模式，用於分析在注入井周圍的瞬應力、壓力、溫度與化學溶質濃度在同時間的變化。為了克服在求解涉及瞬態移流-擴散過程之熱傳輸與溶質傳輸過程時的數值震盪，本文採用一個穩定的有限元素逼近法：亞網格尺度/梯度亞網格尺度方法(SGS/GSGS)。實施假想的二氧化碳飽和水注入碳酸鹽質含水層之數值實驗，初步結果表示完全耦合模型可以成功分析在井孔周圍的岩石受溫度與化學作用下之應力與壓力變化

關鍵字： 石油地質力學、孔隙力學、二氧化碳注入、反應性溶質傳輸、礦物溶解與沉澱、有限元素方法

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Coupled THMC modeling of CO_2 injection by finite element methods

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ABSTRACT

Geological CO_2 sequestration has been proposed to mitigate greenhouse gas emissions. Massive CO_2 injection into subsurface formation involves interactions among pressure and temperature change, chemical reactions, solute transport, and the mechanical response of the rock; this is a coupled thermal–hydraulic–mechanical–chemical (THMC) process. Numerical modeling of CO_2 injection around the wellbore area can provide information such as changes in rock properties as well as stress and pressure changes, and this helps better predict injectivity evolution and leakage risk. In this paper, a fully coupled THMC model based on finite element methods is presented to analyze the transient stress, pressure, temperature and chemical solute concentration changes simultaneously around an injection well. To overcome these numerical oscillations in solving the transient advection–diffusion equations involved in the heat transfer and solute transport processes, we employ a stabilized finite element approach, the subgrid scale/gradient subgrid scale method (SGS/GSGS). A hypothetical numerical experiment on CO_2 saturated water injection into a carbonate aquifer is conducted and preliminary results show that the fully coupled model can successfully analyze stress and pressure changes in the rock around a wellbore subjected to thermal and chemical effects.