以熱-水-力耦合數值模式探討清水地熱案場簡化模型之抽注水交互作用行為

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摘要

地熱發電是台灣再生能源發展中重要的項目之一，其中位於宜蘭縣大同鄉的清水地熱案場為台灣發展最早且相當成功的案例，目前已進入商業運轉階段。然而，地熱發電效益取決於生產的熱水溫度，其可能因為抽注水的管理不當而造成溫度下降，進而降低發電效率，甚至導致地熱井之產能嚴重衰退而沒有經濟效益。因此，本研究利用熱-水-力耦合(thermal-hydraulic-mechanical coupling)數值模擬方法，評估現有抽注水操作下岩體中溫度場的變化狀況，並嘗試以現有各井體資料，評估合適的抽注水方案。因此，本研究以清水地熱案場先建立簡化模型，並進行參數敏感度分析，以了解不同參數設定對熱-水-力耦合模擬的影響。本研究首先蒐集前人針對清水地熱案場進行之地質調查與相關研究成果、地層材料的各項物理性質參數，以及發電廠運作時的抽注水量、水溫等資料；以多物理場模擬軟體 COMSOL Multiphysics，建立簡化的三維地質模型，並考慮地層內部熱傳、水流及固體變形之間的交互作用，建立熱-水-力耦合數值模式。研究中先進行了長時間的模擬使案場達到穩定狀態，再加入地熱井的生產及回注進行模擬，最後透過調整水力梯度、抽注水量及回注水溫等參數，了解這些參數對模擬結果的影響，提供後續模擬的參考。

關鍵字： 清水地熱案場、簡化地質模型、熱-水-力耦合數值模式、參數敏感度分析。

Exploring the interaction of water extraction and injection in a simplified Model of the Chingshui geothermal field using thermal-hydraulic-mechanical coupling numerical models

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Abstract

Geothermal power generation is a vital component of renewable energy development in Taiwan. The commercially operational Chingshui geothermal field, located in Datong Township, Yilan County, represents one of Taiwan's earliest and relatively successful projects in this field. However, the efficiency of the geothermal power generation depends on the temperature of the hot water produced, which can decrease due to improper water extraction management. Therefore, this study employs a thermal-hydraulic-mechanical (THM) coupling numerical simulation approach to assess the variations in the subsurface temperature field under current water extraction practices. The research initially establishes a simplified model for the field and conducts a parameter sensitivity analysis to understand the impact of different parameter settings on simulations. The study begins by collecting prior geological surveys, research findings, physical properties of geological materials, and data on water extraction volumes and temperatures during power plant operations. Utilising the multiphysics simulation software COMSOL Multiphysics, a simplified geological model is then constructed. The interactions between heat transfer, fluid flow, and solid deformation within the subsurface are considered, thus creating a THM coupling numerical model. The simulation starts with a long-term simulation to reach a steady state for the field, followed by the simulation of well production and injection. Finally, this study investigates the influence of parameters on simulation results, thereby providing a reference for subsequent simulations.

Keywords: Chingshui geothermal field, simplified geological model, thermal-hydraulic-mechanical coupling numerical simulation, parameter sensitivity analysis.