International Journal of Heat and Mass Transfer, vol.253, pp.127418-1-127418-24, December, 2025.

Thermal interaction of slender geothermal boreholes with strong groundwater flows

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Abstract-

Geothermal boreholes benefit from the presence of aquifers, as they promote heat exchange with the ground. Adequate modeling of this interaction is essential for the optimal design of geothermal heat exchangers, ensuring both the required thermal efficiency and economic viability of the installation. The state of the art provides an appropriate theoretical framework for creeping groundwater flows, when the Peclet number of the flow remains much smaller than unity. Although this situation is common in many installations, real-world scenarios involving high-permeability soils or energy piles can result in Peclet numbers of order unity or higher. In these cases, current models fail to correctly capture the velocity field near the borehole, leading to unsatisfactory results or the need of empirical tuning parameters. The present work aims to fill this gap in the literature by employing asymptotic expansion techniques to develop a mathematically rigorous and physically consistent model that captures the effects of strong groundwater flows. Apart from demonstrating excellent accuracy compared to high-fidelity numerical simulations, the proposed model provides a critical evaluation of the strengths and limitations of the state of the art.

Index Terms- Geothermal heat exchangers; AquifersThermal interaction; Matched asymptotic expansions; Moderate Peclet numbers

Citation:
Rico, J.; Hermanns, M. "Thermal interaction of slender geothermal boreholes with strong groundwater flows", International Journal of Heat and Mass Transfer, vol.253, pp.127418-1-127418-24, December, 2025.