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PORE-SCALE MODELLING OF STRUCTURED PACKED BED FOR APPLICATION IN ROCK THERMAL ENERGY STORAGE

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ABSTRACT

Rock thermal energy storage is a promising addition to the current energy storage mix offering a cost-effective and eco-friendly system. Although volume-average method offers a fast solution to the flow through packed bed of particles, its accuracy relies on the precise estimation of viscous and inertial resistances as well as the local interstitial heat transfer between the solid and fluid. In this study, a detailed pore-scale modeling approach with an almost pointwise particle-particle and particle-wall contact model is employed to obtain accurate correlations for the friction factor and heat transfer coefficient for airflow through a packed bed of spherical particles. Three packing lattice structures, namely simple cubic (SC), body-centered cubic (BC), and face-centered cubic (FC) are investigated to analyze the effect of porosity on thermo-fluid performance. Particle diameter is also considered as a critical design parameter, as it significantly influences the flow and heat transfer characteristics. Additionally, the study explores the impact of different superficial velocities on system behavior to study the effect of Reynolds number based on the permeability definition. A crucial aspect that is often overlooked in packed bed thermal energy storage systems is the role of thermal radiation, which becomes particularly significant at high temperatures. In this study, radiation heat transfer is explicitly considered alongside convection and conduction to capture the complete thermal transport mechanisms in the system. Since packed beds inherently exhibit non-negligible radiative exchange between the solid particles, especially at high temperatures (above 600 °C), neglecting radiation can lead to considerable discrepancies in predicting overall heat transfer. The inclusion of radiation effects ensures that the obtained correlations for the heat transfer coefficient and friction factor remain valid over a wider range of operating conditions. The results provide a better understanding of packed bed performance as a storage medium, demonstrating the successful implementation of advanced meshing techniques that do not rely on extensive modifications of the solid-solid or solid-wall contact regions, as is common in the literature. The inclusion of radiation further refines the model by ensuring that all significant heat transfer mechanisms are accounted for, leading to a more comprehensive representation of thermal storage behavior in packed beds.

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