Contribution ID: **973** Type: **Oral 20 Minutes**

Direct pore-scale modeling of thermal dispersion in granular porous media: the effect of medium heterogeneity

Tuesday, 15 May 2018 15:58 (15 minutes)

The thermal interactions of fluid-solid regions occurring at pore-level during non-isothermal flow in porous media is usually characterized by the thermal dispersion coefficient at the macroscale. Thermal dispersion coefficient represents the combined effect of thermal diffusion and mechanical convection on the dynamics of heat transport in a porous medium. Thermal diffusion is the transport of energy due to the temperature gradient whereas mechanical convection arises from the variations of the velocity field inside the medium. These variations in the velocity magnitude and direction are the direct result of the heterogeneous nature of pore space as well as the interaction of fluid and solid regions. In this study, direct pore-level numerical simulations are employed to model flow and heat transport in digital granular porous media with different levels of heterogeneity. The granular porous media are generated based on the swelling sphere reconstruction algorithm with variable grain diameters taken from a particle size distribution. The heterogeneity of these media is characterized by the standard deviation of the distribution. We solve the Navier-Stokes and heat convection-diffusion equations through a fully implicit scheme to obtain the spatiotemporal profiles of velocity and temperature at pore scale, respectively. The pore-scale temperature profiles are then used to compute the macroscopic thermal dispersion coefficient at different values of flow velocity, solid-fluid thermal conductivity ratio, and medium heterogeneity. Finally, the calculated dispersion coefficients are correlated against the relevant dimensionless numbers that describe the characteristics of the fluid-porous media system. The analysis and interpretation of these results provide several new insights on the role of medium heterogeneity in thermal dispersion during flow in granular porous media.

References

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Session Classification: Parallel 5-H

Track Classification: MS 1.27: Pore Scale Processes and Upscaling of Flow and (Reactive) Transport in Porous Media