Modelling of fluid flow in porous materials using a DEM-based novel coupled thermo-hydro-mechanical mesoscopic approach

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Most of the physical phenomena in engineering problems occur under non-isothermal conditions. Moreover, even if the physical system is initially in a state of thermodynamic equilibrium, the physical phenomena or chemical reactions that occur may lead to local temperature changes and consequently to heat transfer. Therefore, understanding heat transfer in particulate systems is of great importance to many engineering applications such as environmental science, chemical and food processing, powder metallurgy, energy management, geomechanics and geological engineering. The need to consider the effect of heat transfer becomes critical in analyses of many multi-field problems in porous and fractured materials. The heat transfer may occur e.g. by diffusion, advection and radiation. Complex coupled thermal-hydraulic-mechanical (THM) processes, including heat transfer, fluid flow and material deformation simultaneously occur and are affected by many non-linear processes.

A novel DEM-based pore-scale thermo-hydro-mechanical model of two-phase fluid flow [1, 2] combined with heat transfer in non-saturated porous materials of very low porosity for fracture propagation is presented. Numerical calculations were carried out for bonded granular specimens with a 3D DEM fully coupled with 2D CFD (based on a fluid flow network) and 2D heat transfer that linked discrete mechanics with fluid mechanics and heat transfer at the meso-scale. The heat transfer was related to both the fluid (diffusion and advection) and bonded particles (conduction). The coupled thermal-hydraulic-mechanical (THM) model was validated by comparing the numerical results with the analytical solution of the classic 1D heat transfer problem. Bonded particle assemblies with two different grain distributions were considered. Perfect accordance was obtained between numerical and analytical outcomes. In addition, the effects of advection on the cooling of a bonded particle assembly were numerically shown. Finally, the relevance of the THM model was shown in a thermal contraction test wherein fracture was taken into account in a bonded particle assembly.

References

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[2] M. Krzaczek, M. Nitka, and J. Tejchman. Effect of gas content in macro-pores on hydraulic fracturing in rocks using a fully coupled DEM/CFD approach. *Int J Numer Anal Methods Geomech*, 45, 234-264, 2021.