Distribution of liquid clusters inside a granular packing by LBM

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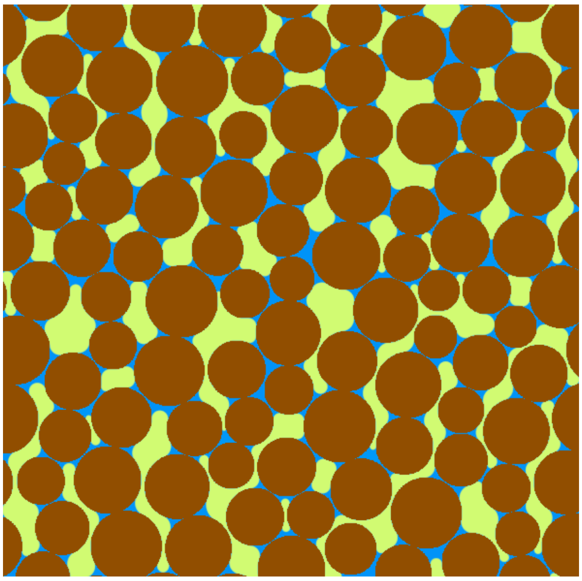
ABSTRACT

Partially wetted granular materials have remained largely unexplored because of the intricate texturing of water in the pore space [1] in spite of its essential role in many natural and industrial processes. We investigate the distribution of liquid in a granular material and its relationship with capillary stresses as the liquid fills gradually and homogeneously the pore space of a 2D granular packing. The distribution of liquid is computed using a single-component multiphase Lattice Boltzmann Method (LBM) [2]. The thermodynamics of phase change is based on Carnahan-Starling's equation of state from which the interactions between liquid, gas and solid are derived using nonlocal potentials. These potentials are calculated between the fluid particles and neighbouring lattice nodes that control the surface tension and contact angle between fluid and solid. A homogeneous grain-liquid mixture is obtained allowing for detailed investigation of the statistics of liquid distribution inside the packing at increasing degree of saturation. A percolation algorithm is employed to identify the liquid clusters and to determine their volume and connectivity with the surrounding grains. The internal pressure of the clusters is analysed as a function of liquid content [3]. We are thus able to obtain the global liquid-retention curve as well as the forces acting on the grains. The tensile stress carried by the grains as a function of the amount of condensed liquid reveals four distinct states with a peak stress occurring at transition from a primary coalescence process, where the cohesive strength is carried mostly by the grains, to a secondary process governed by the increase of the liquid cluster volumes. Finally, we show that the evolution of capillary states is correctly captured by a simple model accounting for the competing effects of the Laplace pressure and grain-liquid interface.



REFERENCES

[1] Scheel, M., Seemann, R., Brinkmann, M., Di Michiel, M., Sheppard, A., Breidenbach, B. & Herminghaus, S. 2008 Morphological clues to wet granular pile stability. Nature Materials 7 (3), 189–193.
[2] Kupershtokh, A.L., Medvedev, D.A. & Karpov, D.I. 2009 On equations of state in a lattice Boltzmann method. Computers and Mathematics with Applications 58 (5), 965 – 974.
[3] Delenne, J.-Y., Richefeu, V., Radjai, F. 2015 Liquid clustering and capillary pressure in granular media, J. Fluid Mech. Rapids 762.