Reorganization of liquid menisci between solid grains during evaporation/condensation of water in a wet porous medium

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ABSTRACT

When a small amount of liquid water is present inside a granular medium, it is well known that it is located between the grains, and these menisci form like bridges. Mechanical aspects of this special configuration, called also pendular regime, have been studied by Mitarai and Nori [1] and by others, but without taking into account the mass transfer mechanisms which occur when the medium is heated. In a given control cell (whose typical size is of order of magnitude larger than that of the grain), the distribution of these menisci depends on many parameters as local temperature and pressure, geometrical configuration of the solid parts, and physicochemical aspects linked to surface tension and roughness of the grains, just to name a few. When humidity varies, for example during an evaporation or condensation process, the shape of the menisci changes a lot, because some liquid bridges may break, and this can strongly affect the effective thermal conductivity.

We consider in this paper a simple situation where all grains are perfect spheres and water is pure. A slight disorder is allowed for both their size and position, leading to variable gaps between the spheres, some of them being in contact. An initial given mass of water is introduced in the cell, and is distributed on all the gaps. The localization is then numerically determined by minimizing the surface energy and by using the Kelvin law, with the main assumption that all liquid menisci are axisymmetric around the lines joining two spheres. Each liquid meniscus shape is computed by solving a differential algebraic system of equations, stating that the total curvature is constant in an axisymmetric coordinates frame. Physical properties like surface tension and liquid/solid contact angle are input parameters. The mass of water is taken as the main control parameter, and we study the reorganization of the liquid menisci, especially their surface area variation, because it is an important parameter for a global model of the evaporation phenomenon in wet porous media.

A further work will consist of the numerical computation of the heat flux across the domain in order to find the effective thermal conductivity, which will then be seen as an extension of the paper [2].

REFERENCES

[1] Mitarai N. and Nori F.: *Wet granular materials*, Advances in Physics, vol 55, 2006, pp 1-45

[2] Canot, É., Delannay R., Mansour S., Muhieddine M. and March R.: *Effective thermal conductivity of a wet porous medium – Presence of hysteresis when modeling the spatial water distribution for the pendular regime*. Proc. of Seventh Int. Conf. on Thermal Engineering (ICTEA), Marrakesh, Morocco, May 6-8 2014; Hasnaoui M. and Saghir M. Z. Eds, ISBN 1-926769-19-6 (CD-ROM edition). Also submitted to ASME J. of Heat Transfer in a revised form (PDF draft)