Strong non-linear behavior of the effective thermal conductivity of a wet porous medium

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Abstract

We consider the great heating of the soil surface leading to the water phase change within a wet porous medium. Experimental temperature curves show that there is always a long plateau (up to one hour) at 100 degrees which is difficult to reproduce by numerical simulations, when using an ordinary continuous model for the heat transfer in the soil. We suspect that the global thermal conductivity changes a lot according to the humidity present in the pores, then suitable models for this effective conductivity must be used.

In this work, we propose a simple approach to derive some effective conductivity laws via a 2D granular model of circular solid cylinders, packed in some regular ways, with the presence of a variable quantity of liquid water, which forms identical meniscii in the gap around each contact point of the cylinders. The liquid contact angle is taken as a control parameter. The doubly periodic pattern is then reduced to a minimal computational domain using the symmetries of the system. The steady heat equation is numerically solved in this small domain, containing three different media (solid, liquid and air) using a Mixed Finite Element scheme. When the liquid fraction becomes more and more smaller, some difficulties arise due to the high contrast between the conductivity of air and those of the solid part, so that extrapolation must be used to estimate accuratly the heat flux through the domain.

Numerical results show that the effective conductivity has a strong non-linear behavior versus the liquid fraction of the water in the porous granular medium. Even if the 2D geometry is not directly applicable to the 3D real granular medium, we think that he can give some ideas to extend the results to our wet porous medium. The application of our work takes place in archaeology, where we study prehistoric fires in order to recover the hearths usage.

References

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