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Pseudo-Thermodynamics of Immiscible Two-Phase Flow in Porous Media: Differential Geometry and Convenient Coordinates

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The problem of immiscible and incompressible two-phase flow in porous media can be recast in terms of the average seepage velocity of the wetting- and non-wetting fluids and a novel velocity called the co-moving velocity, which has the potential of simplifying the theoretical description of macroscopic flow properties [1]. The theory is based on degree-1 Euler homogeneity of the total volumetric flow rate through the porous medium, and the framework takes on the appearance of a thermodynamic theory. The co-moving velocity is the quantity that bridges the gap between the measurable seepage velocities and the abstract thermodynamic velocities that appear in the thermodynamic theory. It has been shown both numerically and experimentally that the co-moving velocity has a particularly simple behaviour [2], and understanding the role of this quantity in a more general theoretic setting might aid our intuition for this abstract velocity.

We will present different interpretations of the transformation from the seepage velocities to the total seepage- and co-moving velocity in the context of a pseudo-thermodynamic theory with as few variables as possible. This will lead us to make the connection between the flow quantities and differential geometry, and show that one is able to regain results from previous works and uncover new descriptions of the flow by convenient coordinate-changes on the space of extensive pore-areas. We discuss a general description of the flow-quantities based on vector fields, and the relation between our framework and the broader field of geometric thermodynamics.

Participation

In-Person

References

[1] Hansen, A., Sinha, S., Bedeaux, D., Kjelstrup, S., Gjennestad, M. A., & Vassvik, M. (2018). Relations Between Seepage Velocities in Immiscible, Incompressible Two-Phase Flow in Porous Media. Transport in Porous Media, 125(3), 565–587. http://dx.doi.org/10.1007/s11242-018-1139-6

[2] Roy, S., Pedersen, H., Sinha, S., Hansen, A. The Co-Moving Velocity in Immiscible Two-Phase Flow in Porous Media. Transp Porous Med 143, 69–102 (2022). https://doi.org/10.1007/s11242-022-01783-7

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