THERMODYNAMIC MODELING OF FLOWS THROUGH POROUS MEDIA

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While chemical reactions are ruled by thermodynamics, flows in porous media are often studied on the basis of hydrodynamics. Nevertheless, several authors [1, 2, 3, 4, 5] have shown over the years that thermodynamics is also a valid foundation for flow modeling.

This talk presents a thermodynamic derivation of heat and mass transfers in porous media. We introduce the classical equilibrium thermodynamics of the different parts of the porous medium (matrix, fluids and interfaces) and apply the local equilibrium assumption on the representative elementary volume (REV) to obtain a consistent thermodynamic description of the porous medium system in the framework of the continuum approach. By working with the balance equations of mass, internal energy and entropy, we derive the local production of entropy. This term includes the dissipation due to interactions and transfers inside the REV (between matrix, fluids and interfaces) and through the REV (fluxes). Assuming the thermal and chemical local equilibria, and a linear regime for flux-gradient relations, we retrieve relations compatible with the well-known laws of Darcy for the fluid velocities and Maxwell-Stefan for the diffusion. The obtained flux-gradient relations for diffusion also include the Soret's and Dufour's effects. The classical capillary pressure curve is obtained as a direct consequence of the equilibrium of the interfaces and is subject to a strong constraint for three or more phases. Finally, we propose a system of partial differential equations for the heat and mass transfers in multiphase and multicomponent flows through porous media. This formulation relies on a unique set of primary variables (no variable switch) and exposes a symmetric structure.

References

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