COUPLING CONCEPTS FOR MULTIPHASE POROUS MEDIUM AND FREE FLOW SYSTEMS

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Fluid flows in coupled free flow and porous medium systems describe a wide spectrum of environmental settings and industrial applications (evaporation from the soil influenced by the wind, wood drying, filters, fuel cells). Solving coupled problems on the microscale is infeasible for many practical applications since it requires detailed information about porous medium morphology and topography which is usually unknown and it is of high computational complexity. At the macroscale, the system is described as two different continuum flow domains (free flow, porous medium) separated by a sharp interface or a transition region of thickness $d > 0$. Different models are usually used in the two flow regions, and correct specification of coupling conditions which are applied at the transition zone between the two flow systems is essential for a co mplete and accurate mathematical description of flow and transport processes in compositional systems. Both theoretical and computational macroscale coupling approaches are available for single-phase single-component systems and for free flows that are in general parallel to the porous medium. Generalization and extension of coupling concepts to multiphase multicomponent systems, possibly curved interfaces and arbitrary flow directions is an area in need of advancement. Recently, the sharp interface coupling concept has been extended to a two-component non-isothermal flow containing two fluid phases inside the porous medium and a single fluid phase in the free flow region, but it is restricted to flat interfaces and flows that are parallel to the porous layer. Sharp interfaces can not store and transfer mass, momentum and energy, and coupling conditions are jump conditions. A general transition region approach has been developed for the coupling of flow systems with components and more than one fluid phase. This coupling formulation includes the macroscale flow and transport behaviour at the possibly curved interface between the flow regions. Such a model formulation is developed in the context of thermodynamically constrained averaging theory. The transition region is averaged in the direction normal to the boundaries of the free flow and porous medium domains being joined that leads to the reduction of spatial dimensionality, and the macroscale system equations are restricted to the two dimensional surface. Unlike sharp interface approximations, models for the transition region resolve the transport of mass, momentum and energy in directions tangent to the averaged direction, and coupling conditions are differential equations that generalize jump conditions in classical sharp interface models.