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Master's Thesis

Coupled Freeflow and Porous Media Flow Systems:Development of a (Navier-)Stokes-Brinkman Model

Submitted by
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Abstract

Coupled free flow and porous flow are ubiquitously available in nature and this is also used in different industries and studies. Instances of transport and exchange processes driven by interfaces can be found in various contexts, such as soil evaporation, water management in fuel cells, or food drying. Porous medium flows are primarily viscous flows that are greatly impeded by unclear internal flow boundaries or pore geometries. On the other hand, free flows are characterized by both inertial and viscous flows that are minimally impeded by well-defined flow boundaries. In general, the Navier-Stokes equations are commonly used to depict the momentum transport in viscous fluid systems, serving as a description for free flow domains. Conversely, Darcy's equation is utilized to simulate fluid movement through porous materials, distinguishing it as a specialized equation for such scenarios. The flow systems can be evaluated on the representative elementary volume (REV) scale. The two-domain approach can solve a system of coupled flow domains through interface conditions. It is also possible to simulate similar systems using a single domain approach with the (Navier-) Stokes-Brinkman equation.

The objective of this thesis was to develop a model that introduces the Brinkman term to the existing Navier-Stokes simulation environment implemented in DuMu$^{\text{x}}$. A single-domain approach was thus developed and afterwards, this setup was tested with a setup of two-domain approach. The results of this (Navier-) Stokes-Brinkman model (single-domain approach) were then compared to the results of the two-domain approach. Four types of geometric setups were used for the study.

At first, a geometric setup was developed for the single-domain approach. A lens was used in the setup to resemble a porous region. The (Navier-) Stokes Brinkman equation was used to develop this single-domain apporach. Subsequently, three other geometric setups were developed to use in this study. Each of these geometric setups was further divided into two different approaches: a single-domain approach and a two-domain approach. In the single-domain approach the whole domain (both free flow and porous region flow) was developed using (Navier-) Stokes Brinkman equation and in the two-domain approach two different sets of equations were used (Navier-Stokes equation for free flow and Darcy's law for porous medium flow). Beavers-Joseph-Saffman condition was used for coupling the two different domains for the two-domain approach. For the single-domain approach no coupling was required. Results of the single-domain approach and the two-domain approach were compared and found satisfactory. The

results of the study show that the (Navier-)Stokes Brinkman model works well for the coupled free flow and porous media flow system.