Reynolds Number Dependent Porous Media Flow Using the Brinkman Equation

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Introduction

Porous media fluid dynamic modeling has been widely explored and utilized in many academic and industrial applications. Cross flow filtration being one attractive application, whereas the fluid and filtrate flow parallel the porous media, and thereby induce shearing stress along the membrane surface to reduce fouling. In modeling porous media flow, it is common to describe the porous domain by global averaging since modeling individual pores becomes computationally expensive. The well known Darcy law describes flow in porous media without accounting for shear induced momentum transfer. The Brinkman equation is an extension of Darcy's law which accounts for shear induced momentum transfer and has experimentally shown to be significant within many flow regimes.

Brinkman's equation prescribes the momentum balance equation as a function of the permeability and porosity of the porous membrane. The permeability is traditionally assumed to be a constant material property and a function of the porous material's pore shape and size. Physically, the permeability can be perceived as the effective resistance of the fluid flow. Computational experiments have been performed in modeling of fluid flow in individual micro-pores using the well established Navier-Stokes equation. An analogous model of these micro-pores was produced using the Brinkman equation. The Brinkman model was shown to agree with the micro-pore model within a limited flow regime. In practical applications of cross flow filtration, the pressure variation along the porous wall would render a Brinkman equation model of this porous domain inaccurate. It is theorized that a more robust porous media model can be designed using the COMSOL Brinkman equation with the permeability set as a user defined function of the local pore Reynolds number.

The proceeding will aim to empirically and theoretically adjust the permeability used in the Brinkman equation such that it is a function of the local Pore Reynolds number.

Use of COMSOL Multiphysics

The steady state incompressible Navier-Stokes module is used to model the flow through actual micro-pores. This model will serve as an accurate depiction of a realized micro-pore flow. The chemical engineering momentum transport module for porous media flow is used to describe the analogous Brinkman equation model. A user defined function will be used in place of the Brinkman equation's permeability in order that it accurately depicts the actual micro-pore model.

Expected Results

It is expected that a semi-empirical formula will be obtained for the permeability used in the Brinkman equation.

Conclusion

The Brinkman equation's ability to model porous media of known structure can be inaccurate if not adjusted. This study would also pose a novel approach to verifying and adjusting trusted phenomenological equations, such as the Brinkman equation, by using trusted benchmark models.

Reference

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