Contribution ID: **711** Type: **Oral Presentation**

The permeability of pillar arrays in microfluidic devices: an application of Brinkman's theory towards wall friction

Wednesday, 24 May 2023 14:30 (15 minutes)

Darcy's law describes the flow of Newtonian fluids through bulk porous media as the product of the applied pressure difference, the fluid's viscosity and the medium's permeability. Brinkman extended Darcy's law with a viscous stress term, thereby enabling boundary conditions to the flow field at the surface of the medium. The validity of Brinkman's term, and the value of its effective viscosity, have been heavily debated since their introduction nearly 75 years ago. We use experiments and Multibody Dissipative Particle Dynamics (MDPD) simulations to study flows through ordered and disordered pillar arrays in microfluidic channels of limited height. We find that the simulated velocity profiles are well described by an expedient interpretation of Brinkman's theory. Depending on the solid volume fraction and pillar arrangement, the effective viscosity varies between two and three times the bulk fluid viscosity. The calculated effective permeabilities of the flow devices, combining the flow resistances due to the pillars and the walls by Brinkman's theory, agree well with the experimental data. This approach enables fast and accurate estimates of the effective permeability of micropillared chips. The simulated force distributions over the walls and pillars require an effective viscosity equal to the bulk viscosity and an elevation-dependent permeability of the pillar array.

Participation

In-Person

References

The permeability of pillar arrays in microfluidic devices: an application of Brinkman's theory towards wall friction,
Thejas Hulikal Chakrapani, Hanieh Bazyar, Rob Lammertink, Stefan Luding, Wouter K. den Otter, Soft Matter, 2023, DOI: 10.1039/d2sm01261h

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Session Classification: MS11

Track Classification: (MS11) Microfluidics and nanofluidics in porous systems