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Flow through microchannels with topographically patterned wall: a spectral theory for arbitrary groove depths

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Abstract

Current technology allows us to build microfluidic channels, which are so thin that incidental and/or surface topographical features engineered for applications such as microfluidic mixing/separations can present significant constrictions and dilatations to the flow passage. Considering such situations, pressure-driven laminar incompressible flow through an infinitely wide channel, one of whose walls has sinusoidal grooves running along the flow direction, is investigated through an accurate semi-analytical and grid-free spectral approach, without placing any restrictions on the pattern amplitude. In the special limits of small pattern amplitude, thick and thin channels , the spectral model recovers asymptotic predictions earlier reported in the literature. The spectral model is also used to provide new closed-form estimates for permeability and effective slip at an order of asymptotic accuracy higher than those currently available from the literature. The effect of unequal degrees of intrinsic hydrodynamic slippage on the corrugated and plane walls is also studied asymptotically. The predictions from the spectral model, which are obtainable with very low computational expense, are also cross-validated against finite-element-method based simulations. In the thick channel limit, the predictions from the spectral model are quantitatively consistent with results from recent molecular dynamic (MD) simulations conducted by Guo et al. [1, Physical Review Fluids, 1(7), 074102, 2016]. The newly proposed and existing closed-form asymptotic predictions are also assessed numerically against the spectral model. In the long-wave limit, the permeability of

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