A higher-order Hele-Shaw approximation for micro-channel flows

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The classic hydrodynamic Hele-Shaw problem is revisited in the context of evaluating the viscous resistance to low-Mach compressible gas flows through shallow non-uniform microfluidic configurations (whose depths are small in comparison with all other characteristic dimensions). Earlier calculations have demonstrated that failure to satisfy the no-slip condition at the channel lateral walls severely restricts the applicability of the resulting approximation. To overcome this we have extended the calculation to incorporate an inner solution in the vicinity of the side walls (which, in turn, allows for the characterization of the effects of non-rectangular channel cross sections) and its matching to an outer correction. Comparison with finite-element simulations demonstrates a remarkably improved accuracy relative to the leading-order Hele-Shaw approximation. This suggests the present scheme as a useful alternative for the rapid performance estimate of microfluidic devices.

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