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RESEARCH PAPER

Two- and three-dimensional lattice Boltzmann simulations of particle migration in microchannels

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Abstract The use of two-dimensional (2D) numerical simulations with a reduced particle-based Reynolds number (*Re*) for studying particle migration in a microchannel with equally spaced multiple constrictions was investigated. 2D and 3D colloidal lattice Boltzmann (LB) models were used to simulate particle-fluid hydrodynamics. Experiments were conducted with inert microparticles in a creeping flow in a microflow channel with symmetric wall obstacles. Lowering *Re* in 2D simulations by a factor of *R* (the dimensionless particle radius in LB simulations) resulted in a close match between numerically computed and experimentally obtained particle velocities, indicating that *Re*-based dimensional scaling was needed to capture the 3D particle flow dynamics in 2D simulations of experimental data. We captured particle displacement motion in a microchannel with symmetric inline obstacles in 2D simulations, where symmetry in the flow field was broken by local disturbances in the flow field due to particle motion, indicating that asymmetry in channel geometry is not the sole cause for particle displacement motion. Particle acceleration/deceleration around each constriction followed the same pattern, but each constriction acted like a particle accelerator in 2D and 3D simulations, in which particles exhibited progressively higher velocities in each subsequent constriction. Particles migrated across multiple streamlines in converging and diverging flow zones in a creeping flow, which calls into question the use of steady streamlines for calculating transient particle flow. Monotonicity in particle acceleration toward the constriction and deceleration beyond the constriction was broken by interparticle hydrodynamic interactions leading to more pronounced particle migration across multiple streamlines.

Keywords Computational methods in fluid dynamics · Low Reynolds number (creeping) flows · Hydrodynamics · Hydraulics · Hydrostatics

1 Introduction

Migration of deformable (Faivre et al. 2006) or rigid particles (Ai et al. 2009) in a microchannel with a constricted passage was experimentally and numerically considered in previous studies to quantify the effects of the constrictive geometry on particle trajectories, acceleration, and hydrodynamic drifts in the context of particle separation and ordering. In these studies, a rectangular or funnel-like single constriction was used to generate converging and diverging flow fields along which particle migration was monitored under controlled pressure drops across a microchannel. In this paper, we experimentally and numerically analyzed particle migration under a creeping flow regime in a microchannel with a series of equally spaced and symmetric constricted passages imposed by rectangular channel wall obstacles. The first objective of this paper

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