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Effects of particle-fluid coupling on particle transport and capture in a magnetophoretic microsystem

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Abstract: A numerical analysis is presented of the effects of particle?fluid coupling on the transport and capture of magnetic particles in a microfluidic system under the influence of an applied magnetic field. Particle motion is predicted using a computational fluid dynamic CFD-based Lagrangian?Eulerian approach that takes into account dominant particle forces as well as two-way particle?fluid coupling. Two dimensionless groups are introduced that characterize particle capture, one that scales the magnetic and hydrodynamic forces on the particle and another that scales the distance to the magnetic field source. An analysis is preformed to parameterize capture efficiency with respect to the dimensionless numbers for both one-way and two-way particle?fluid coupling. For one-way coupling, in which the flow field is uncoupled from particle motion, correlations are developed that provide insight into system performance towards optimization. The difference in capture efficiency for one-way versus two-way coupling is analyzed and quantified. The analysis demonstrates that one-way coupling, in the dilute limit, provides a conservative estimate of capture efficiency in that it overpredicts the magnetic force needed to ensure particle capture as compared with a more rigorous fully coupled analysis. In two-way coupling there is a cooperative effect between the magnetic force and a particle-induced fluidic force that enhances capture efficiency. Thus, while one-way coupling is useful for rapid parametric screening of particle capture performance, more accurate predictions require two-way particle?fluid coupling. This is especially true when considering higher capture efficiencies and/or higher particle concentrations.