

## Coupled Particle-Fluid Transport and Magnetic Separation in Microfluidic Systems with Passive Magnetic Functionality

**Authors:** Saud Khashan, Edward Furlani

**Abstract:** A study is presented of coupled particle-fluid transport and field-directed particle capture in microfluidic systems with passive magnetic functionality. These systems consist of a microfluidic flow cell on a substrate that contains embedded magnetic elements. Two systems are considered that utilize soft- and hard-magnetic elements, respectively. In the former, an external field is applied to magnetize the elements, and in the latter, they are permanently magnetized. The field produced by the magnetized elements permeates into the flow cell giving rise to an attractive force on magnetic particles that flow through it. The systems are studied using a novel numerical/closed-form modelling approach that combines numerical transport analysis with closed-form field analysis. Particle-fluid transport is computed using computational fluid dynamics (CFD), while the magnetic force that governs particle capture is obtained in closed form. The CFD analysis takes into account dominant particle forces and two-way momentum transfer between the particles and the fluid. The two-way particle-fluid coupling capability is an important feature of the model that distinguishes it from more commonly used and simplified one-way coupling analysis. The model is used to quantify the impact of two-way particle-fluid coupling on both the capture efficiency and the flow pattern in the systems considered. Many effects such as particle-induced flow-enhanced capture efficiency and flow circulation are studied that cannot be predicted using one-way coupling analysis. In addition, dilute particle dispersions are shown to exhibit significant localized particle-fluid coupling near the capture regions, which contradicts the commonly held view that two-way coupling can be ignored when analysing high-gradient magnetic separation involving such particle systems. Overall, the model demonstrates that two-way coupling needs to be taken into account for rigorous predictions of capture efficiency, especially fo