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Simulation of Focusing of Diamagnetic Particles in Ferrofluid Microflows with a Single Set of Overhead Permanent Magnets

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Abstract : Microfluidics is a technology that small amounts of fluids are manipulated using channels with dimensions of tens to hundreds of micrometers. At present, this significant technology is required for several applications in some fields, including disease diagnostics, genetic engineering, and environmental monitoring, etc. Among these fields, manipulation of microparticles and cells in microfluidic device, especially separation, have aroused general concern. In magnetic field, the separation methods include positive and negative magnetophoresis. By comparison, negative magnetophoresis is a label-free technology. It has many advantages, e.g., easy operation, low cost, and simple design. Before the separation of particles or cells, focusing them into a single tight stream is usually a necessary upstream operation. In this work, the focusing of diamagnetic particles in ferrofluid microflows with a single set of overhead permanent magnets is investigated numerically. The geometric model of the simulation is based on the configuration of previous experiments. The straight microchannel is 24mm long and has a rectangular cross-section of 100μm in width and 50μm in depth. The spherical diamagnetic particles of 10μm in diameter are suspended into ferrofluid. The initial concentration of the ferrofluid c_0 is 0.096%, and the flow rate of the ferrofluid is 1.8mL/h. The magnetic field is induced by five identical rectangular neodymium−iron− boron permanent magnets (1/8 × 1/8 × 1/8 in.), and it is calculated by equivalent charge source (ECS) method. The flow of the ferrofluid is governed by the Navier–Stokes equations. The trajectories of particles are solved by the discrete phase model (DPM) in the ANSYS FLUENT program. The positions of diamagnetic particles are recorded by transient simulation. Compared with the results of the mentioned experiments, our simulation shows consistent results that diamagnetic particles are gradually focused in ferrofluid under magnetic field. Besides, the diamagnetic particle focusing is studied by varying the flow rate of the ferrofluid. It is in agreement with the experiment that the diamagnetic particle focusing is better with the increase of the flow rate. Furthermore, it is investigated that the diamagnetic particle focusing is affected by other factors, e.g., the width and depth of the microchannel, the concentration of the ferrofluid and the diameter of diamagnetic particles.

Keywords : diamagnetic particle, focusing, microfluidics, permanent magnet
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