Abstract

The interwinding of magnetic field with hydrodynamics has opened up possibilities of unique applications in diverse domains such as noiseless high-speed printing, liquid-cooled loudspeakers, rotary shaft seals, pressure seals, nuclear power generation, vacuum feed-throughs, cell and tissue engineering, drug delivery, noninvasive measurements, separation processes, magnetized gas-fluidized beds etc. Nevertheless, due to the complex coupling between magnetism and hydrodynamics, the field of ferrohydrodynamics is not as developed as classical fluid dynamics till date. In the present work, attempts have been made to develop a thorough understanding of a number of fundamental problems of magneto-fluidic systems.

A detail formulation of the governing equations conferring hydrodynamics and thermal energy transport during flow of ferrofluid is presented. Some classical flow situations such as Couette-Poiseuille flow, cavity driven flow have been taken up as case studies. We find that flow separation can be suppressed under certain conditions by applying uniform magnetic field of suitable strength. For two-dimensional flow arrangement, anisotropy in thermal transport is observed when a constant magnetic field is applied. Closed-form expressions for the velocity and temperature fields have been proposed for unidirectional flow arrangements with the approximation of the small spin velocity and zero spin diffusion, applicable for larger channels at higher field strength, as suggested by our numerical prediction.

We present an analytical model that characterizes the influences of the magnetic field strength and its distribution, as well as the effect of the magnetic susceptibility of the paramagnetic medium on the duration required to form diamagnetic structures of various shapes and dimensions. Unlike the continuum-based model used to treat ferrofluidic flow, a particle-based model is developed and used to evaluate the trajectories of individual diamagnetic particles. For validating experiments, we use Polybead R carboxylate microspheres, since their density and magnetic susceptibility are close to those of biological cells and use gadopentetic acid solution to produce the paramagnetic medium. Governed by the same physics, we demonstrate for the first time that structures of diamagnetic particles can be assembled in a surrounding diamagnetic which reverses sinusoidally. This, in turn, imparts an oscillating motion to the nanoparticle. We investigate the effect of nanoparticle diameter, wettability of the nanoparticle surface, and frequency of the alternating magnetic field on the formation and growth of nanobubbles around the nanoparticle. We reported the effect of nanoparticle diameter, wettability of the nanoparticle surface, and frequency of oscillation of the applied magnetic field on the bubble formation and growth. Keywords: Ferrofluid, Spin Velocity, Magnetization Relaxation, Nusselt Number, Numerical Simulation, Diamagnetic Particles, Magnetic Nanoparticle, Molecular Dynamics, Nanobubble. medium. To provide proof of this concept, we assemble graphene microparticles in pure water.

Finally, we study the formation and growth of nanobubbles around an oscillating magnetic nanoparticle suspended in a viscous liquid using a molecular dynamics approach. Magnetic manipulation of the nanoparticles is advantageous as the system can be controlled remotely in a non-invasive manner. We have taken hexagonal close-packed (HCP) cobalt nanoparticles for the present analysis. The nanoparticle is put under a gradient magnetic field, the direction of which reverses sinusoidally. This, in turn, imparts an oscillating motion to the nanoparticle. We investigate the effect of nanoparticle diameter, wettability of the nanoparticle surface, and frequency of the alternating magnetic field on the formation and growth of nanobubbles around the nanoparticle. We reported the effect of nanoparticle diameter, wettability of the nanoparticle surface, and frequency of oscillation of the applied magnetic field on the bubble formation and growth.

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