World Academy of Science, Engineering and Technology
International Journal of Biomedical and Biological Engineering
Vol:17, No:04, 2023

Analysis of Lift Force in Hydrodynamic Transport of a Finite Sized Particle in Inertial Microfluidics with a Rectangular Microchannel

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Abstract : Inertial microfluidics is a competitive fluidic method with applications in separation of particles, cells and bacteria. In contrast to traditional microfluidic devices with low Reynolds number, inertial microfluidics works in the intermediate Re number range which brings about several intriguing inertial effects on particle separation/focusing to meet the throughput requirement in the real-world. Geometric modifications to make channels become irregular shapes can leverage fluid inertia to create complex secondary flow for adjusting the particle equilibrium positions and thus enhance the separation resolution and throughput. Although inertial microfluidics has been extensively studied by experiments, our current understanding of its mechanisms is poor, making it extremely difficult to build rational-design guidelines for the particle focusing locations, especially for irregularly shaped microfluidic channels. Inertial particle microfluidics in irregularly shaped channels were investigated in our group. There are several fundamental issues that require us to address. One of them is about the balance between the inertial lift forces and the secondary drag forces. Also, it is critical to quantitatively describe the dependence of the life forces on particle-particle interactions in irregularly shaped channels, such as a rectangular one. To provide physical insights into the inertial microfluidics in channels of irregular shapes, in this work the immersed boundary-lattice Boltzmann method (IB-LBM) was introduced and validated to explore the transport characteristics and the underlying mechanisms of an inertial focusing single particle in a rectangular microchannel. The transport dynamics of a finitesized particle were investigated over wide ranges of Reynolds number ($20 < Re < 500$) and particle size. The results show that the inner equilibrium positions are more difficult to occur in the rectangular channel, which can be explained by the secondary flow caused by the presence of a finite-sized particle. Furthermore, force decoupling analysis was utilized to study the effect of each type of lift force on the inertia migration, and a theoretical model for the lateral lift force of a finite-sized particle in the rectangular channel was established. Such theoretical model can be used to provide theoretical guidance for the design and operation of inertial microfluidics.

Keywords : inertial microfluidics, particle focuse, life force, IB-LBM
Conference Title : ICMN 2023 : International Conference on Microfluidics and Nanofluidics
Conference Location : Chengdu, China
Conference Dates : April 13-14, 2023