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INERTIAL MICROFLUIDICS

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ABSTRACT

The microfluidic systems developed for focusing and sorting cells and biological objects are based on hydrodynamic interactions responsible for the cross-flow migration of selected objects suspended in a carrier liquid. This effect has long research history, inspired by intriguing redistribution of red blood cells in capillaries and already one century ago observed by pathologist Fåhræus. It stimulated experiments and numerical studies to elucidate existence of lateral hydrodynamic forces redistributing suspended particles, droplets and filaments across the channel. One of the important messages appearing from these studies is that the inertial forces usually neglected in microfluidics play an important role for proper interpretation of the cross-flow migration of particles and droplets. Presence of residual inertial forces and breakup of the flow symmetry in case of suspended deformable objects or complex channel configurations leads to irreversible hydrodynamics, imposing limited use of so called Stokesian approximation in the theoretical models. In most of practical configurations found in microchannels the flow is diverted by junctions, meanderings, and sudden shape variations. Careful look at the flow patterns indicated serious discrepancies with numerical models based on Stokesian hydrodynamics. In fact even molecular dynamics studies performed for deformable drop-like inclusions indicate presence of cross-flow migration, hence use of simplified Stokesian hydrodynamics even at molecular scales is disputable. It becomes crucial to underline limits of creeping-flow linearity and necessity for full Navier-Stokes modelling of microfluidic flows, even if old-school tutors set arguments based on famous G.I Taylor demonstration of low Reynolds number flow reversibility.

The proposed MS will be devoted to studies dedicated to help microfluidic experimentations in planning and discovering hydrodynamic mechanisms responsible for efficient controlling of flow focusing, mixing, and cell sorting configurations, taking into account full nonlinearity of the underlying hydrodynamics. This area is of special interest for biologists, where elastic membrane of transported cells triggers additional flow response nonlinearities. Similar problems are present in transporting of long, deformable molecules, or filaments (e.g. DNA in flow analysis).