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TUMBLING, ROTATING AND OSCILLATING: 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 a 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 irreversible hydrodynamics responsible for redistributing suspended particles, droplets and filaments across the channel. 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. Careful look at the flow patterns indicated serious discrepancies with numerical models based on Stokesian hydrodynamics [1]. Tumbling, coiling, and cross-flow migration of long filaments, resembling DNA behaviour, gave us motivation to look closer at conditions literally forbidding application of simple, linear modelling of hydrodynamic problems. We will try to extract formulations defining sources of nonlinearities based on the local flow parameters, like spatial and temporal gradients of velocity, replacing the commonly used in hydrodynamics global Reynolds number.

At slightly higher flow rates, but still in the regime of the laminar flow, local velocity gradients generated by the interface corrugation induce cross-flow temporal and spatial fluctuations which are especially pronounced when combine with temperature gradients [2]. Their effect efficiently increases mass and heat fluxes desired in several practical applications of microfluidic devices. Some of these "geometry induced" flow nonlinearities will be discussed in the second part of the talk.

[1] Lateral migration of electrospun hydrogel nanofilaments in an oscillatory flow, S. Pawlowska et al, PLOS ONE 12(11):e0187815 (2017).

[2] Natural convection and thermal drift, A. Abtahi, J. M. Floryan. J. Fluid Mech., 826, 553-582 (2017).