Inertial Particle Focusing Dynamics in Trapezoid Straight Microchannels: Application to Continuous Particle Filtration

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Abstract : Inertial microfluidics has emerged recently as a promising tool for high-throughput manipulation of particles and cells for a wide range of flow cytometric tasks including cell separation/filtration, cell counting, and mechanical phenotyping. Inertial focusing is profoundly reliant on the cross-sectional shape of the channel and its impacts not only on the shear field but also the wall-effect lift force near the wall region. Despite comprehensive experiments and numerical analysis of the lift forces for rectangular and non-rectangular microchannels (half-circular and triangular cross-section), which all possess planes of symmetry, less effort has been made on the 'flow field structure' of trapezoidal straight microchannels and its effects on inertial focusing. On the other hand, a rectilinear channel with trapezoidal cross-sections breaks down all planes of symmetry. In this study, particle focusing dynamics inside trapezoid straight microchannels was first studied systematically for a broad range of channel Re number (20 < Re < 800). The altered axial velocity profile and consequently new shear force arrangement led to a cross-laterally movement of equilibration toward the longer side wall when the rectangular straight channel was changed to a trapezoid; however, the main lateral focusing started to move backward toward the middle and the shorter side wall, depending on particle clogging ratio (K=a/Hmin, a is particle size), channel aspect ratio (AR=W/Hmin, W is channel width, and Hmin is smaller channel height), and slope of slanted wall, as the channel Reynolds number further increased (Re > 50). Increasing the channel aspect ratio (AR) from 2 to 4 and the slope of slanted wall up to Tan(α)≈0.4 (Tan(α)=(Hlonger-sidewall-Hshorter-sidewall)/W) enhanced the off-center lateral focusing position from the middle of channel cross-section, up to ~20 percent of the channel width. It was found that the focusing point was spoiled near the slanted wall due to the dissymmetry; it mainly focused near the bottom wall or fluctuated between the channel center and the bottom wall, depending on the slanted wall and Re (Re < 100, channel aspect ratio 4:1). Eventually, as a proof of principle, a trapezoidal straight microchannel along with a bifurcation was designed and utilized for continuous filtration of a broader range of particle clogging ratio (0.3 < K < 1) exiting through the longer wall outlet with ~99% efficiency (Re < 100) in comparison to the rectangular straight microchannels (W > H, 0.3 ≤ K < 0.5).

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