Principia Lift Force – Empirical measurements of $F_L$ stray from modern theories

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Inertial focusing is a phenomenon that allows for focusing, separation, isolation, concentration and fluid exchange of particles in fluid samples where few may be of interest and appear outnumbered by a myriad of others, making their detection and analysis difficult – if not impossible. As remarkable examples, microfluidic systems capable of focusing and separating circulating tumour cells from blood [1,2] and pathogenic bacteria from water [3,4] have been demonstrated.

Much progress has been done in the last decades, both in the theoretical understanding [5] and the applicability of the phenomenon [6]. Yet, being frank, still nowadays most practical systems are the result of intensive lab-work and the evaluation of large numbers of prototypes. The reason for this is partly that modern theories for the Lift Force ($F_L$) point in different directions and claim different scaling laws, making the fine engineering of devices unfeasible.

Here we present indirect empirical measurements of $F_L$ up to $Re_C \approx 240$. The results stray from current theories and reveal a fairly simple scaling of $F_L$ that we hope helps in designing future systems and scaling up/down those already performing well.

$$F_L \sim \frac{U_m \alpha^4}{W^3}$$

where $U_m$ is the maximum velocity of the flow, $\alpha$ the hydrodynamic diameter of the particle and $W$ the channel width. Please note in particular the linearity in relation to $U_m$, also observed experimentally by Zhou & Papautsky in 2013 [7].

The measurements were done by directly confronting the secondary flow ($F_D$) against $F_L$ in High Aspect Ratio Curved systems (HARC Systems [8]). The flow rate ($Q$) was raised in systems with fixed $R$ until $F_D$ surpassed $F_L$ and the particles crossed over to the outer wall, see Fig. 1.

Figure 1. (A) Direct opposition of the Secondary flow and the Lift Force in HARC systems. (B) Experimental data showing when $F_D$ surpasses $F_L$ – (Particles cross over to the outer wall for $Q$ over the line).
References


