Asymmetric Rayleigh streaming induced by large amplitude vibrations around a sharp obstacle

Geyu Zhong[1,2,3], Liu Yingwen[2], Xiaofeng Guo[1], Laurent Royon[1], Philippe Brunet[3]

[1] Université Paris Cité, LIED, UMR 8236, CNRS, F-75006, Paris, France
[2] Key Laboratory of Thermo-Fluid Science and Engineering of MOE, School of Energy and Power Engineering, Xi'an Jiaotong University, Xi'an, 710049, Shaanxi, China
[3] Université Paris Cité, MSC, UMR 7057, CNRS, F-75006, Paris, France
philippe.brunet@u-paris.fr

The steady streaming generated near solid walls by the periodic forcing of a viscous fluid, is known to be strongly enhanced near sharp structures, owing to centrifugal effects that lead to the generation of an intense jet from the sharp tip[1,2]. This flow has been shown to provide efficient active mixing in microchannels, due to strong transverse velocity. The forcing is often prescribed by acoustic transducers, but it can also be generated by low-frequency time-periodic flow ensured by mechanical vibrations. In this paper, we study the flow structure generated by low-frequency forcing (typically 10 Hz) around a sharp tip. Using Direct Numerical Simulations, we extract both the time-periodic and steady responses within a large span of amplitude of vibrations. When the amplitude is smaller than the tip radius of curvature, we recover the flow structure observed at higher frequencies (> 1 kHz) in previous studies, namely an intense symmetric central jet and a quadratic dependence for the characteristic streaming velocity with the oscillating velocity $v_s \sim v_a^2$. At higher amplitudes, such a scaling no longer holds and the streaming flow pattern loses its left-right symmetry. We then analyse the mechanisms of the instability from the careful examination of the instationary flow fields, and we propose possible mechanisms for such a flow transition involving the coupling between the streaming jet and instationary vorticity[3].

References

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