Particle-Fluid Interactions in Acoustically Driven Convection Systems: A Study on Microbead Dynamics

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Recent developments in the field of droplet microfluidics, especially in the field of acoustofluidics have played a significant role in the advancement of advanced biological research and zero-gravity aerospace research. This study investigates the particle dynamics of microbeads subjected to acoustic forces and convective heat transfer induced by an external source. The study involves the numerical study as well as the results are validated using Smoothed Particle Hydrodynamics (SPH-meshless method). The primary focus is to analyze the response of microbeads to convective heat transfer while in a levitated state due to acoustic forces. By examining their behavior under these conditions, the research aims to enhance the understanding of particle-fluid interactions in acoustically driven convection systems. Endaylalu et.al. (1) investigated the mixing performance in a Y-junction microchannel with acoustic streaming. Zhang et.al. (2) studied the impacts of high-frequency ultrasound-induced acoustic streaming that affects flow and heat transfer characteristics in microchannels. The study by Muller et.al. (3) on the thermoviscous effects by ultrasound standing wave resonance in a long straight microfluidic channel containing a Newtonian fluid. The findings reveal that the microbeads exhibit distinct motion patterns influenced by the interplay between acoustic levitation and convection currents.

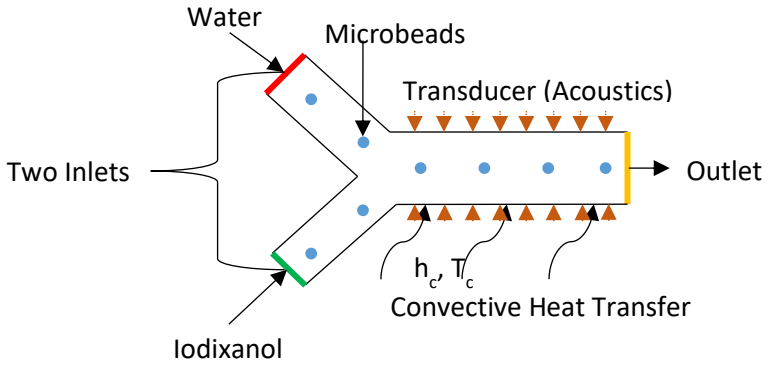

Figure 1: Significance of combined acoustic and heat transfer in microbead's dynamics

References:

[1] Endaylalu, S. A., & Tien, W.-H. (2022). A numerical investigation of the mixing performance in a Y-junction microchannel induced by acoustic streaming. *Micromachines*, *13*(2), 338. doi:10.3390/mi13020338

[2] Zhang, D., Kang, D., Fu, L., Lan, M., Tang, S., Yao, S., Lei, Y. (2025). Investigation of flow and heat transfer characteristics in microchannel with high-frequency ultrasound. *Thermal Science and Engineering Progress*, (103305), 103305. doi:10.1016/j.tsep.2025.103305

[3] Muller, P. B., & Bruus, H. (2014). Numerical study of thermoviscous effects in ultrasound-induced acoustic streaming in microchannels. *Physical Review. E, Statistical, Nonlinear, and Soft Matter Physics*, *90*(4), 043016. doi:10.1103/PhysRevE.90.043016