Experiments and simulation of a dielectrophoretically oscillating microparticle

Stuart J. Williams¹, Steven T. Wereley²

1: Mechanical Engineering Department, University of Louisville, Louisville, Kentucky, USA, stuart.williams@louisville.edu
2: Birck Nanotechnology Center and School of Mechanical Engineering, Purdue University, West Lafayette, Indiana, USA, wereley@purdue.edu

Keywords: Micro PIV, Microfluidics, dielectrophoresis, particle-fluid interactions

A complete understanding of fluid-particle interactions is important in understanding the dynamics between biological microorganisms and their environment. It is necessary to observe these and similar particles in suspension in order for a complete investigation of particle-fluid interactions. However, previous investigations of cellular response to fluid flow have limited their analysis to rigidly adhered cells to the wall of microchannels.

These type of experiments are not representative of their biological environments where the bioparticle (for example: red blood cells or phytoplankton) are freely suspended within the liquid. Rather, observation of suspended particles would better resemble their environment. Further, if these suspended particles could undergo experimentally-controlled translation within the fluid (while remaining in suspension), additional time-transient microfluidic phenomena could be observed.

The technique described herein involves a dielectrophoretic technique to trap and translate a particle within a microchannel. Flow visualization including µPIV has been incorporated to enable hydrodynamic investigations. A spherical polystyrene bead 10.1 μm in diameter is trapped in suspension within a microchannel with dielectrophoresis.

The trapped particle is translated laterally in a periodic manner, with the distance between the furthest oscillating points is approximately 40 μm. The particle translates within the plane of focus, which is important for accurate µPIV analysis. The period of oscillation for a 20 volt peak-to-peak signal was approximately 2 seconds. The velocity of the particle is proportional to the square of applied AC signal magnitude.

Numerical simulation of the dielectrophoretically agitated microparticle is compared to experimental observation. Results and challenges of incorporating micro-resolution particle image velocimetry (µPIV) with this electrokinetic agitation technique is discussed. Preliminary µPIV analysis was demonstrated with a statically captured particle held in suspension with dielectrophoresis. Bulk fluid motion (26 μm/s) was applied and microfluidic velocimetry results are shown.

A system capable of dielectrophoretic trapping and oscillation of microparticles is critical for future biologically relevant hydrodynamic fluid-particle investigations. Fluid-particle interactions with non-spherical particles are also of interest. With appropriate planning, PIV tracer particles can be minimally influenced by unwanted AC electrokinetic effects and future DEP systems can be optimized to reduce Joule heating.

These preliminary results demonstrated with commercially available items provide an important foundation for future adaptations investigating microfluidic-particle interactions incorporating µPIV.

Fig. 1. An illustration of the electrothermal flow setup. A cross-sectional view is shown. The tracer particles appear as ellipses, whose shape depends on their out-of-plane location.