Re-suspension of particles in an oscillating grid turbulent flow

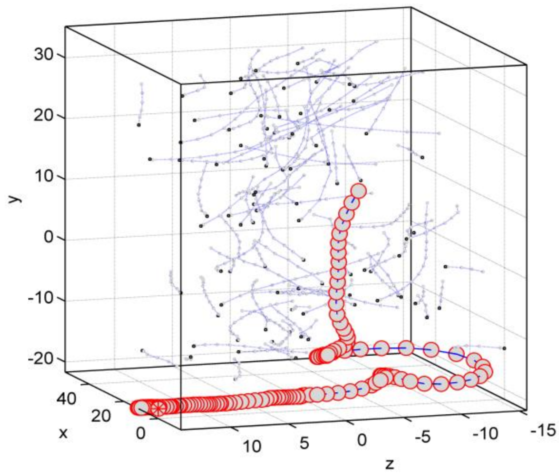
Traugott Hadar[1], Liberzon Alex[1]
[1] *Turbulence Structure Laboratory, School of Mechanical Engineering, Tel Aviv University, Tel Aviv, Israel.*

Particle re-suspension in liquid environments is an important mechanism in a variety of practical applications, such as: particle filtration, oil production, migration of surface contaminants [3] and even particulate transport in respiratory ways. Over the years, different criteria and models have been proposed to define threshold conditions for particle incipient motion. Despite a significant progress in the field during the past decades, description of the mechanisms responsible for the initiation of particle detachment from a surface and re-entrainment into suspension remains a challenge. This is partially due to the technical difficulties to quantify the forces applied on the particles and the collection of high-resolution data of flow measurements and particle displacement simultaneously.
The majority assumes particle-turbulence interaction to have a major influence on the phenomena [6]. Observations led to models that consider turbulent coherent structures with vertical velocity component ,v, exceeding the particle settling velocity, v_s , to be responsible for the incipient motion. Since in boundary layers velocity components are proportional to the friction velocity, $u^*=(\tau_w/\rho)^{0.5}$, the critical conditions for the initiation of suspension (pick up or lift off) are defined in terms of friction velocity, i.e. $u^*/v_s>1$(Bagnolds' condition) [1]. In flows without mean shear it was proposed that root-mean-square of turbulent fluctuating velocity or turbulent kinetic energy, i.e $(u'^2+v'^2+w'^2)/2$ characterizes the re-suspension process [2,4].

In this study we continue the previous research [5] and investigate the the necessary conditions for initial entrainment (pick up, lift off) of spherical particles from a smooth bed into a zero-mean-shear turbulent flow in an oscillating grid chamber in the transitional range of particle size Reynolds numbers $2< Re_p <500$. Particle Image Velocimetry (PIV) was used to determine the properties of turbulent flow. Three-Dimensional Particle Tracking Velocimetry (3D-PTV) was used to synchronously measure local flow conditions and track the entrainment of individual test particles through the various phases of the re-suspension. The combination of the experimental methods and different types of particles (tracers and test particles) allow to identify key mechanisms, utilizing direct high resolution observation of particle motion at the beginning, during and after the lift-off.

Combination of PIV and 3D-PTV results allow quantification of turbulent flow and its relation to the lift-off process. A significant positive spatial correlation is observed between the lift-off rates, Reynolds stresses and horizontal fluctuating velocity. 3D-PTV results show that at lift-off, flow near the particle have predominant instantaneous vertical velocity component well above Bagnolds' condition, while the horizontal velocity component is weakly related to the lift-off events. In addition, we show that turbulent kinetic energy of the flow near the particle may be considered only as a necessary but not as a sufficient condition in order to characterizes lift-off ratios under different forcing frequencies.

(a)



(b)

Figure: (a) 3D-PTV measurements under the oscillating grid. **(b)** Isometric sketch of the Lagrangian trajectory demonstrating the incipient motion of a particle as it moves upwards and the trajectories of the tracer particles surrounding it.

References

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