Suspensions of very heavy inertial particles

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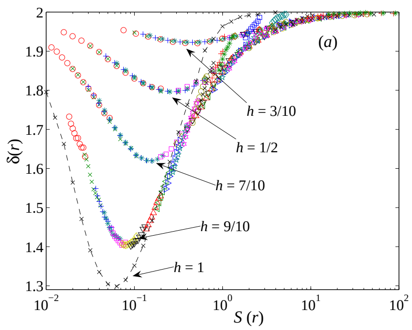
In many natural phenomena and industrial processes one encounters suspensions within turbulent flows, in which the suspended particles have finite extension and a mass density possibly different from that of the carrier flow. A salient feature of suspensions of such so-called 'inertial particles' is the presence of strong inhomogeneities in the spatial distribution of particles. This paper studies the dynamics of such suspensions in the limit of *very* heavy particles, that is when the response time of the particles is larger than any characteristic time-scale of the turbulent carrier flow.

In this limit, the particles behave as if suspended in a Gaussian flow which is delta-correlated in time. Apart from this model flow being exact in the limit of very heavy particle, the model has another conceptual advantage: In real turbulent flows, cluster formation is due to two effects, (i) particles are expelled from persistent vortical regions of the flow and (ii) the particles lag behind the fluid flow. By studying a flow with a very small correlation time, we isolate the latter effect. This allows for a systematic analysis of dissipative dynamics effects on the evolution of the particles. The model is used to single out the mechanisms leading to the preferential concentration of particles. This is done for (1) particles which are smaller than the smallest active scale of the flow, the so-called 'Kolmogorov scale' which exhibit a spatially smooth carrier flow as well as for (2) particles for which the carrier flow is spatially rough.

1. Particles smaller than the Kolmogorov scale experience a smooth random velocity field. Their dynamics depends only on the so-called 'Stokes number', i. e. the particle response time non-dimensionalized by a characteristic time scale of the carrier flow. We quantify possible cluster formation with the help of tools of dissipative dynamical systems. In particular, we determine the behaviour of the Lyapunov exponent, the stretching rate as well as the correlation dimension as a function of the Stokes number. A maximum of clustering is observed for intermediate values of the Stokes number.



2. While for smooth flows, the particles form fractal clusters, this is not the case for particles suspended in rough self-similar flows. The particles rather distribute inhomogeneously with a statistics that only depends on a *local* Stokes number, given by the ratio between the particles' response time and the turnover time associated to the observation scale. As the tools from dissipative dynamical systems do not apply to non-smooth flows, inhomogeneities in the particle distribution are studied in terms of a local Hölder exponent of the particles velocity field and a local correlation dimension. The latter is shown in the figure, as a function of the local Stokes number $S(r)$ for a planar carrier flow, for various values of the Hölder exponent h. The limit of $h = 1$ corresponds to smooth flows. Deviations of the local correlation dimension $\delta(r)$ from the space dimension 2 signal clustering. Note that within the considered model, particle clustering is reduced by the fluid roughness.

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