Mini-Projet : Inertial particles in oscillating flows

Student : - Adviser : Roxane Letournel

1 Introduction

This mini-project aims at understanding the basic dynamics of inertial particles in turbulent flow fields. The model used for the inertial particles in this project is commonly used for studying a very wide range of physical phenomena, from sand storms to engine sprays, or alumina particles in solid fuel rocket boosters. In most physical applications, the carrying phase is a fluid following Navier-Stokes-like equations. However, in order to allow for simple theoretical results, the flow fields in this project will be chosen analytical. They will nonetheless aim at reproducing some of the essential features that can be encountered in turbulent flows.

The objective of the mini-project is threefold.

- First, relying of a theoretical development proposed in some reports [4] produced a few years ago, tackle a very simple problem in 1D where a particle is set in a sinusoidal velocity field and observe the various dynamics depending on the Stokes number of the particle.

  Secondly the gaseous flow field is supposed to be a traveling sinusoidal wave at a given velocity. At first, simulate the case and observe the phase separation described in the report by a former post-doctoral fellow Taraneh Sayadi [5].

- The second part of the study is a theoretical one, based on the bifurcation and limit points based on the previous configuration.

- Finally, based on these results, an extension is proposed to more complex and many-dimensional flows (2D - Taylor-Green / 3D turbulent) depending on time.

2 An inertial particle in a sinusoidal gaseous flow field

In the first part, the purpose is to understand and present the dynamics of a particle in a gaseous flow field based on Stokes drag law and neglecting the other forces on the particle. The objective is first to identify the critical Stokes number for which there is particle trajectory crossing [1] and then to simulate it using a simple time scheme of your choice (based on what we have studied in the course).

Then, we consider a traveling sinusoidal gaseous flow field and observe the influence of the wave velocity on the dynamics. Based on the proposed report, reproduce the phase separation, where some particles are "attracted" by the high strain rate points (maximal derivative of the gaseous flow field), whereas others are drifting and oscillating. Reproduce such behavior with your solver.

3 Bifurcation analysis and homoclinic trajectory

Based on the study of Taraneh Sayadi proposed in the documents, propose an analysis of the bifurcation taking place and explain the definition of a second critical Stokes number.

4 Extension to more complex velocity fields

We now turn to a more realistic 2D/3D velocity fields.

- At first, simple patterns such as Taylor-Green field flows in 2D/3D can be explored.
- Then, the flow field can be represented by spectral models in the form of a sum of sines based on the work of [3] and [2]. Attention is given to preserve incompressibility and the characteristic scales of energy, space and time of a turbulent flow.

Analytical integration of the flow field allows for a study of the rate of convergence of the numerical methods seen in the course.

References

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[4] M. Massot. A few points on acoustic waves and spray dynamics. Rapport technique de collaboration avec le CORIA, 2005.

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