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Instabilities and transition in three-dimensional flows with rotation

**CLUSTER FORMATION FOR INCOMPRESSIBLE VISCOUS FLUID/RIGID
SOLID PARTICLE MIXTURES IN ROTATING CYLINDERS**

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1. Problem presentation and previous results

In a previous publication (ref. [1]) the authors discussed the numerical simulation of particle cluster formation in a rotating cylinder containing a fluid/particles mixture, the fluid (resp., the particles) being incompressible, viscous and Newtonian (resp., rigid solid and spherical). More precisely, assuming that the gravity field is vertical, that the cylinder has a circular cross-section, that its rotation axis is horizontal, and that the particle density is larger than the fluid density, the simulation reported in [1] have shown, in particular, the following behavior:

Suppose that at time zero the fluid and the particles are at rest, the particles lying on the bottom part of the cylinder; suppose next that the cylinder starts rotating around its axis: if the angular velocity is large enough one observes the formation of particle clusters as shown in Figure 1(a) (borrowed from [1]). Figure 1(b) shows the projection of the particle population (160 particles here) on a vertical plane orthogonal to the rotation axis.

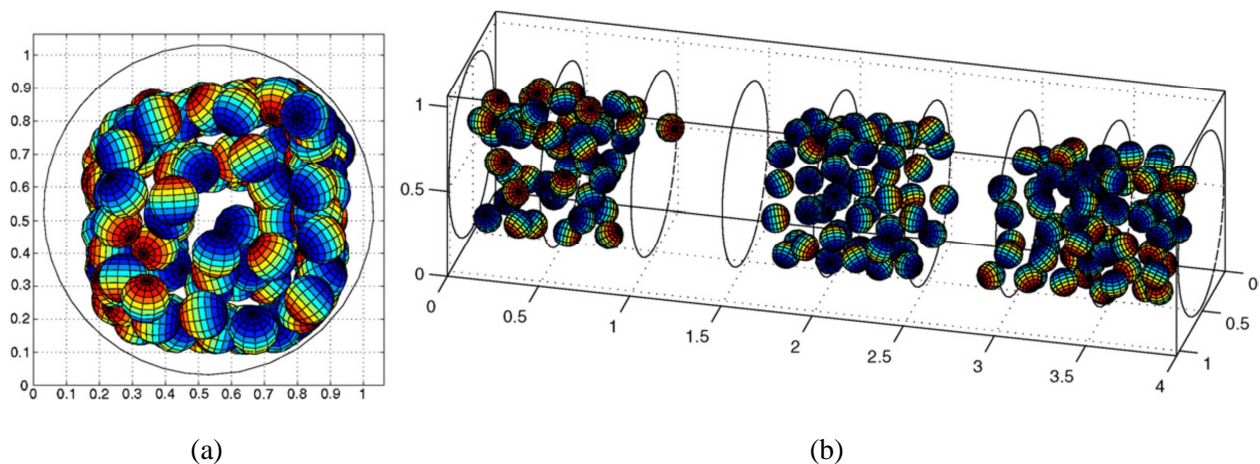


Figure 1. Cluster formation in a rotating cylinder.

Actually, the simulation results reported in [1] agree with the experimental ones available in the literature (some of these references are given in [1]).

The computational methodology used in [1] relies on several ingredients, such as: finite element methods for the space discretization, time discretization by operator-splitting, a Lagrange multiplier based fictitious domain method allowing the fluid flow computations to be done in the full cylinder using a fixed grid, despite the fact that the physical flow region is a time variable subset of the full cylinder.

2. Objectives of the present study

Our objectives in this presentation are to go beyond [1] (still using the same computational methodology) by considering:

- (i) The effect of the size of the particle populations on the formation of clusters.
- (ii) The effect of gravity and fluid/particle density ratio on the formation of clusters.

Concerning (ii), our simulations strongly suggest that cluster formation does not take place in the *neutrally buoyant* case, that is, when the particles have the same density than the surrounding fluid. It is worth noticing that this result is in agreement with the results from laboratory experiments.

Reference

- [1] PAN, T-W., R. GLOWINSKI, S. HOU, Direct numerical simulation of pattern formation in a rotating suspension of non-Brownian settling particles in a fully filled cylinder, *Computers and Structures*, **85**, (2007), 955–969.