EPSC Abstracts
Vol. 13, EPSC-DPS2019-2066, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Particle Size Segregation in Granular Asteroids

Jérémy Sautel and Nicolas Taberlet
Univ Lyon, ENS de Lyon, Univ Claude Bernard, CNRS, Laboratoire de Physique, F-69342 Lyon, France

Abstract

Our study focuses on the particle size segregation problem in granular asteroids: indeed, most images of granular asteroids show a clear surface size segregation between their different components. To explain this, terrestrial segregation mechanisms have to be adapted to the specific gravitational environment of an asteroid and the diversity of the perturbations that it may encounter. To investigate how these ingredients could lead to a segregation, we use a SSDEM code that applies periodic perturbations to a simulated aggregate. We study the influence of all relevant physical parameters for this situation, especially by defining characteristic values for the quality and the quickness of an aggregates's segregation.

1. Introduction

Although many studies have focused on 'Brazil nut effect' inspired problems [1], segregation in a self-gravitating aggregate remains unknown. The motivation for this study comes from recent observations of the surface of granular asteroids like Itokawa (mainly due to missions Hayabusa and Hayabusa 2 [2]), which reveals the presence of many of the biggest components of the asteroids on their surface. We can also notice that this surfacic display is not uniform and some areas are filled with much smaller components, like fine dust. The explanation of this phenomenon is of main interest to try and understand the geology of asteroids and to make predictions about the composition of their layers under the surface. As a matter of fact, no measurements focused on this deeper composition were possible during the last missions.

Through numerical experiments, we were able to study granular segregation in a 2-dimensions aggregate that is periodically mechanically disturbed. This enabled us to show that segregation on asteroids is not due only to a surfacic effect, but results from mechanical processes involving the whole aggregate, leading to predictions for the compositions of deeper layers of granular asteroids. Varying the relevant parameters of the simulations gave us important clues about the phenomenon that can be piloting segregation in asteroids. In particular, we studied the influence of the intensity of the perturbations and of the friction coefficient between the grains, as well as the contribution of the various degrees of freedom of the grains (translational and rotational). We also study how far the specific gravity fields of asteroids entail differences with terrestrian granular segregation: we distinguish the role of the intensity and the goemetry of the field.

2. Segregation characteristics

The simulated 2 dimensions aggregates are obtained by the collapse of $N = 1000$ grains (800 'small' and 200 'big') under an imposed central gravitational field $g \propto r$, where r is the distance to the center of the field. This process is much more efficient in time than the computation of all the gravitational forces between the 1000 grains. Then, this imposed field is periodically perturbated with an associated period T. The 'perturbation', also called 'quake', consists in an inversion of the field during a time interval T_s: for each non-zero integer n, the field points outwards for $t \in [nT, nT + T_s]$. The value of T is fixed to $12,5$ s and different values of T_s between 0.5 s and 2 s are then used. The fig. 1 shows an example of evolution from a mixed state to a segregated state during the simulations.

A normalised segregation degree Ψ is defined with respect to the average distance of 'big' and 'small' grains to the center of the aggregate. Ψ is ranging from 0 for a perfectly mixed state to 1 for a completely segregated state. In the numerical experiments that compose this study, Ψ was computed right before each perturbation of the asteroid: a typical time evolution is shown by Fig. 2.

By fitting the evolution $\Psi(t)$ with a saturated exponential growth:

$$\Psi(t) = \Psi_\infty \left[1 - \exp\left(-\frac{t}{\tau}\right)\right] \qquad (1)$$

we are able to define two main quantities for each

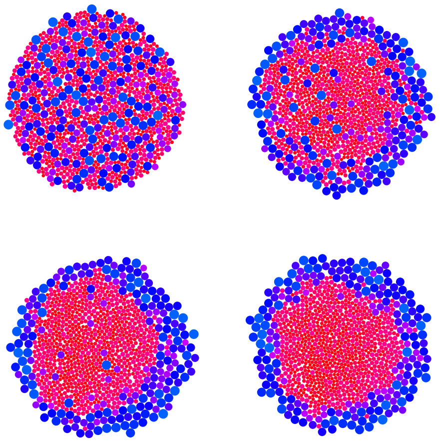

Figure 1: Snapshots of a simulated aggregate at the initial state (top left) after 500 quakes (top right), after 1000 quakes (bottom left) and after 2000 quakes (bottom right). These data were obtained for a friction coefficient $\mu = 0,8$, a perturbation's duration $T_S = 1,25$ s, and a dimensionless momentum of inertia $J^* = 10^4$.

simulation (and therefore, for each set of physical parameters): the quality of the segregation Ψ_∞ and its typical time τ.

3. Analysis and Conclusions

We looked at the evolution of Ψ_∞ and τ with different physical parameters. Although the restitution coefficient e of a grain-grain collision turned out to be of low influence, the friction coefficient μ showed interesting and sometimes unexpected effects, like an optimum in μ for the segregation quickness. As this parameter plays a role both on translational and rotational motion of the grains, we wanted to distinguish these effects. This was made possible thanks to the numerical approach, which enables us to modify the inertia momentum of the grains. We multiplied it by a dimensionless factor J^* and studied the evolution of Ψ_∞ and τ with respect to J^*. As said before, the role played by the specific gravitational field has also been studied, by simulating new aggregates with an imposed field $g \propto z$ (z being an arbitrary direction) instead of the usual one. All this studies provided us with very interesting results, that we intend to show and discuss, with their eventual theoretical explanations, on a poster presentation at the meeting.

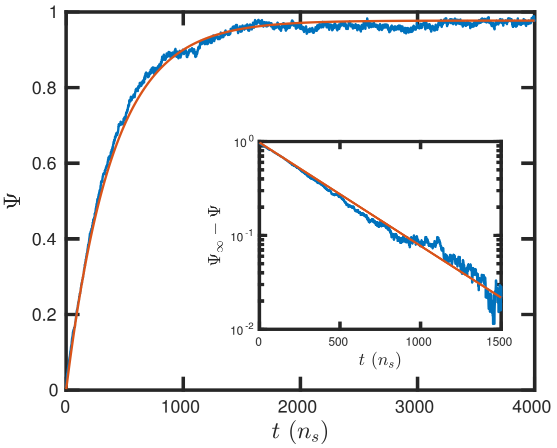

Figure 2: Plot of the segregation degree Ψ as a function of time (in number of perturbations units), computed for the simulation illustrated on Fig. 1. The red curve corresponds to a fit by a saturated exponential growth.

Acknowledgements

The authors acknowledge support from the Ecole Normale Supérieure de Lyon, both through the financial support of the PhD of Jérémy Sautel, and the computational supplies that it offers us for numerical works.

References

[1] M. E. Möbius, B. E. Lauderdale, S. R. Nagel H. M. Jaeger: Size separation of granular particles, Nature, Vol. 414, p. 270, 2001.

[2] Fujiwara, A., Kawaguchi, J., Yeomans, D. K., Abe, M., Mukai, T., Okada, T., ... Barnouin-Jha, O., Science, Vol. 312(5778), pp. 1330-1334, 2006.