Université de Liège

RAPPORT D'ACTIVITE POST-DOCTORAT
2012-2013

Nom et Prénom du chercheur:	**PACHECO VÁZQUEZ Felipe**
Intitulé du projet :	**Confined granular material in a bouncing ball**
Promoteur :	**Stephane Dorbolo, Nicolas Vandewalle**
Date du séjour (début – fin):	**01-04-2012 / 30-09-2013**

1. Synthèse des recherches réalisées:

First research: We studied the formation of granular towers produced when dry sand is poured on a wet sand bed. We called these structures self-assembled granular towers. When the liquid content of the bed exceeds a threshold value **W***, the impacting grains have a non-zero probability to stick on the wet grains due to instantaneous liquid bridges created during the impact. The trapped grains become wet by the capillary ascension of water and the process continues, giving rise to stable narrow towers. The growth velocity is determined by the surface liquid content which decreases exponentially as the tower height augments.
This self-assembly mechanism (only observed in the funicular and capillary regimes) could theoretically last while the capillary rise of water is possible, however the structure collapses before reaching this limit. The collapse occurs when the weight of the tower surpasses the cohesive stress at its base. The cohesive stress increases as the liquid content of the bed is reduced. Consequently, the highest towers are found just above W*.

Second research: We studied the bouncing dynamics of a confined granular system: a hollow body containing small particles therein, that can move freely in the inner space when the body bounces on a solid surface. We concentrated in two aspects: 1) the bouncing dynamics obtained by dropping the body over a solid surface, and 2) the bouncing dynamics obtained over a vertically vibrated plate. First, the restitution coefficient ¤was measured as a function of the inner mass (number of particles N) by releasing the cylinder over a steel solid surface. We found that ¤ decreases from 0.9 (quasi-elastic collision) when the container is empty and decreases as the inner mass (number of particles) augments up to an inelastic collision is obtained when the inner mass is three times the mass of the cylinder. The initial energy is dissipated by numerous particles collisions during a time T proportional to 1/N.
When the system is subjected to vertical oscillations, ¤the restitution coefficient plays a fundamental role. This parameter and the elapsed time between two continuos collisions is measured as a function of the dimensionless acceleration and bifurcation diagrams for different inner where obtained.

Third research: We are studying the compaction dynamics of a magnetic granular monolayer (a vertical monolayer of cylindrical magnets) when it is compressed by a piston. 450 magnets are introduced in a vertical Hele-Shaw cell and with the same dipolar orientation in order to produce repulsion between them. The piston is moved vertically using a step motor to reduce the available space. This generates a rearrangement of the structure. The objective is to measure the force opposed bt the crystal to be restructured and describe how the initial random distribution (relaxed state) evolves to the final hexagonal state.

On the other hand, we developed experiments about the elastic properties of macroscopic granular crystals made of neodimium magnetic spheres. Three different configurations were explored: hexagonal, square and combined crystals. As a result of the dipolar orientation, the strength of the crystal (the capacity to support an applied stress without failure) depends of the configuration. By measuring the tensile, normal and shear stress, we have found a notably higher elasticity in the square structure, while the hexagonal crystal can support a larger stress without deformation before reaching the breaking point. The combination of both properties (elasticity and high ultimate tensile strength) makes the combined structure more resistant to deformation. Theory and simulations will be used to understand and support our findings.

The results of the last experiments will be discussed and analyzed as part of a collaboration between GRASP at the University of Liège and the Institute of Physics of the University of Puebla, in Mexico, see final note at the end of the document.

2. Liste des publications acceptées et soumises:

As a result of these studies, one article was published and a second manuscript is now in preparation:

1. Pacheco-Vázquez, F. , Moreau, F., Vandewalle, N., and Dorbolo, S. Sculpting sandcastles grain by grain:self-assembled sand towers. *Phys. Rev. E* **86**, 051303 , (2012).

2. Pacheco-Vázquez, F. and Dorbolo, S. Rebound of a confined granular material: combination of a bouncing ball and a granular damper. *Scientific Reports* **3**, 2158 (2013). doi:10.1038/srep02158.

3. Pacheco-Vázquez, F. and Dorbolo, S., A grain-filled sphere over a vibrated plate. *In preparation,* (2013).

It is expected to publish two articles as a result of the experiments concerning magnetic granular crystals.

Observations:

Overviews about the first article were also published in the following media:
- In the paper version of the french scientific magazine *Pour la science Vol. 1, (2013)* and in the online version:
http://www.pourlascience.fr/ewb_pages/a/actualite-des-chateaux-de-sable-construits-grain-par-grain-30756.php
- At the website of the University of Liège "Reflexions":
http://reflexions.ulg.ac.be/cms/c_344169/the-mysteries-of-towers-of-sand
-By the magazine *Athena*: Le mystère des tours de sable 286, 38-40, December (2012).

-By the national news RTL-TVI and by the local journal "la Meuse".

3. Les missions scientifiques réalisées (congrès, colloques, courts séjours):

Presentation: "Three unexpected phenomena in Granular matter" as a part of the program "Seminars for pedestrians". This is an every week presentation at the Physics Department in order to present the recent work of doctoral students and postdoctoral researchers.

During this postdoctoral stay I refereed six articles for the APS (American Physical Society) for publication in Phys. Rev. Lett. and Phys. Rev. E. and one article in Granular matter journal.

IMPORTANT OBSERVATION:

I have been accepted in a Tenure track position by the Institute of Physics at the University of Puebla, Mexico, starting in October 1, 2013. The results obtained during my stay at GRASP and the BELSPO-Marie Curie fellowship for the postdoctoral position were crucial to achieve that goal. This is a clear indication of the relevance of the above actions that allows young scientists to start a career as a researcher.