Evaluation of power dissipation in a granular bed disturbed by an intruder a tool to design kneading operations

Julien Lehuen, Jean-Yves Delenne, Abdelkrim Sadoudi, Duri Agnès, Thierry Ruiz

Evaluation of power dissipation in a granular bed disturbed by an intruder a tool to design kneading operations

J. Lehuen[1,2], J-Y. Delenne[1], A. Sadoudi[1], A. Duri[1], T. Ruiz[2]
[1] UMR IATE 1208 CIRAD/INRA/Montpellier SupAgro/Université Montpellier – 2 Place Pierre Viala, 34060 Montpellier cedex 5, France, e-mail : julien.lehuen@supagro.fr, jean-yves.delenne@inra.fr, abdelkrim.sadoudi@inra.fr, agnes.duri@inra.fr
[2] UMR QualiSud 95, CIRAD/Université Montpellier – 15 avenue Charles Flahault, 34093, Montpellier cedex 5, France, e-mail : thierry.ruiz@umontpellier.fr

The study of stress transmission and typologies of motions in a powder bed under low shear condition constitutes a challenging issue to achieve a monitoring of processes which involve particle mobility like kneading or agglomeration process [1]. This work deals with the quantification of the ability of a probe to ensure the particle mobilities in a granular bed disposed in the tank of a reactor. An original experiment had been developed (i) to allow the visualization of the behavior of particles in the neighborhood of an intruder in ascendant vertical motion, and (ii) to measure the drag force applied to an intruder during its extraction from an ensiled granular medium. In order to identify the force propagation in a granular ensiled medium, experiments and Discrete Element Method (DEM) simulations [2] are compared to investigate the extent of force imposed by the blade at (i) different speeds, (ii) different geometric configurations and (iii) different intruder designs.

1. Methods

Experimental device. The granular medium consists of a population of glass beads of 1-2 mm diameter with a small span value. The experimental set-up consists of an open glass cell container (51x100x160 mm) made of transparent glass walls. The filling is provided by a funnel and the flow rate is modulated to reach a controlled static state of the granular packing. A steel probe is especially designed (shape: flat and rectangular, hemispherical, dihedral…and dimensions in regards the particle size and the size of the cell) to fit into the glass container. It is screwed on a rod that is linked to a load cell of a force sensor. The probe is then removed from the granular packing and the drag force is measured.

Numerical simulation. An “own homemade code” in c++ using the DEM is developed to calculus the force of a similar ensiled granular medium under gravity. We increment our code with the coarse graining method and we are now able to give different fields: compactness, stress tensor components, particle velocities. We can explore all the contacts between the particles by the calculus of (i) normal and tangential forces, (ii) moment. Besides DEM gives access to the mobility of the particles (position, velocity and acceleration). With the force and the velocity, the power dissipated by friction and collisions between each particle can be determined. Power dissipation was specially calculated at each time by the component of the dissipated forces (normal and tangential) and the velocity of each particle. The evolution of the repartition of the power dissipated inside the granular bed during the vertical ascension of the intruder, constitutes a criteria to quantify the efficiency of the process (single kneading with high mobilities, strong friction between particle). With this method, influences of different velocities, shapes of the intruder and size of the cell, on the power dissipation, could be determined.

2. Results and discussion

Experimental and numerical simulation result are in good agreement. Drag force and global powder kinetics are fitted. These results show the establishment of different regimes inside the granular bed during the vertical ascension of the intruder. These flowing regimes are correlated with characteristic lengths and allow to distinguish different zones in the granular packing. As a consequence, the power dissipation is not homogeneous inside the granular medium. Besides the repartition of this power depend also on the shape of the intruder, and on the size beneath wall and intruder. We can now purpose an analyze to design different shape of the intruder and used it for different geometrical conditions to correspond at the configuration linked with the specific industrial applications. This study at the particle scale can now be expand at the reactor scale for process of mixing in the food, pharmaceutical industries but also in civil engineering in the case of the cement truck for example.

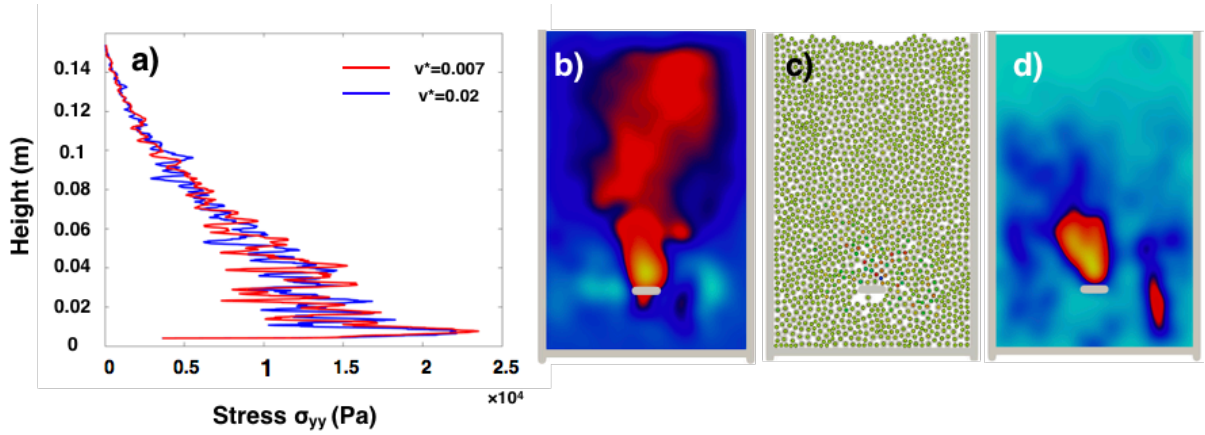

Figure 1. a) drag stress for different velocities of an intruder b) vertical velocity field obtained by coarse graining c) power dissipation inside granular medium d) vertical stress field obtained by coarse graining

Keywords: granular materials; kneading; mixing reactor design; powder dissipation; DEM; coarse graining

References

Weinhart, T., Labra, C., Luding, S., & Ooi, J. Y. (2016). Influence of coarse-graining parameters on the analysis of DEM simulations of silo flow. *Powder technology*, *293*, 138-148.
Fakih, M., Delenne, J. Y., Radjai, F., & Fourcaud, T. (2019). Root growth and force chains in a granular soil. *Physical Review E*, *99*(4), 042903.
Hill, G., Yeung, S., & Koehler, S. A. (2005). Scaling vertical drag forces in granular media. *EPL (Europhysics Letters)*, *72*(1), 137.