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# Experimental and numerical analyses by DEM of the range of a probe in a granular medium

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***Highlights***

- There is vertical stratification within a granular medium located in a reactor.
- The range of force imposed by the blade is all the lower when the speed is high.
- DEM simulations give the structural rearrangement which occurs during trials.
- Spatiotemporal correlations of particle motions observed by PIV could be explained by DEM.

## 1. Introduction

The study of stress transmission and motion typologies 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 ability of a probe to ensure the particle mobilities in a granular bed disposed in the tank of a reactor. An original experiment is developed (i) to allow the visualization of the behavior of particles in the neighborhood of an intruder (*i.e.* a horizontal flat blade design) in ascendant vertical motion, and (ii) to measure the drag force applied to the 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 propagation of the force imposed by the blade at different dimensionless speeds.

## 2. Methods

*Experimental device.* The granular medium is 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 by the output diameter. A flat and rectangular steel probe is especially designed to fit into the glass container. It is screwed on a rod that is linked to a load cell of a texture analyzer (TA.XT2, Table Micro System), which is used as a force sensor. The probe is then removed from the granular packing. The drag force is measured and the velocity field is analyzed by PIV analysis. The visualization of the particle mobilities during the ascendant vertical motion of the probe is carried out using a high-speed camera and then, analyzed by Particle Image Velocimetry (PIV).

*Numerical simulation*. In order to reproduce the experimental conditions, a code using both the DEM and the coarse-graining method is developed to calculate the force network, the stress fields and the solid fraction of the granular medium. It allows us to explore all the contacts network between the particles by the calculus of (i) normal and tangential forces, (ii) moment, (iii) mobility of each particle.

## 3. Results and discussion

Force measurements and PIV technique allow to identify different types of particle motions (compaction, loading and rupture of the chain forces, lateral collapsing, avalanches, etc.) as well as the mechanical state of the granular bed. These behaviors are confirmed by DEM simulations which indicate the evolution of the compactness and the lifetime of intergranular contacts. Fluctuations of stress are identified and depend on the dimensionless blade speed [3]. This result can be explained by successive loading and rupture cycles of horizontal force chains taking place above the blade, leading to fluctuations of the vertical stress. The analysis of spatiotemporal correlations of the velocity fields reveals the existence of a dihedral-shape assembly of grains which constitutes a permanent disturbance zone above the blade during its vertical rise whatever the blade speed. The range of the blade could be defined by a characteristic length links to the development of mobility gradients. A specific study of the velocity gradient generated above the blade is carried out for the different blade speeds.

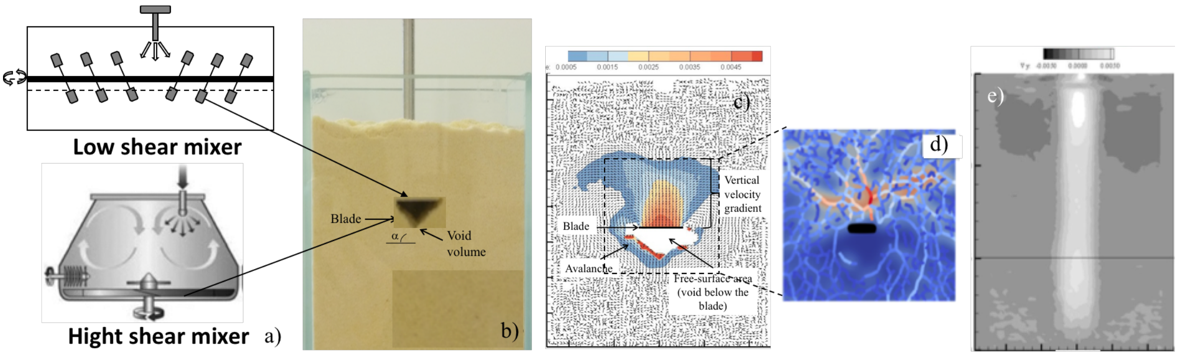


**Figure 1.** From reactors (a) to the experimental device (b) to identify particle mobilities by PIV (c) and DEM simulations (d) focused around the blade and the active and passive zones of mobilities in the granular medium (e).

## 4. Conclusions

Experimental observations coupled with DEM simulation allow to access to the phenomenon at the reactor and particle scales. The analysis of the local force network and the microstructure of the granular medium allows to define characteristic length and time. These parameters could be then used to optimize process control that involves particle mobilities induced by a mechanical input.

### References

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