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Abstract

The classic experience of filling a container with a granular medium poured from a source point reveals the presence of the intergranular force network by the manifestation of the Janssen effect (Janssen, 1895). Indeed, the measurement of the stress applied at the base of the container according to the bed particle height, shows that the static mechanical state of the ensiled granular medium is characterized by the lateral deflection of gravity forces to the walls via the network of intergranular contacts. In order to model this difference from a hydrostatic state, Janssen (1895) purposed to integrate all along the cell, the stress balance established at a layer scale. This equation universally used, is defined with three major hypotheses: (i) lateral uniformity of the vertical stress in each layer, (ii) the lateral stress is still proportional to the vertical stress (definition of the redirection coefficient), and (iii) the sliding threshold condition at the walls. With these assumptions the model describes the experimental profile of the vertical stress with its particular "saturant" slope (Ovarlez and Clément, 2005). If mechanical properties are involved to explain this apparent phenomenon understood as a static equilibrium, the free surface analysis during pouring correlated to the local mechanical state allows to indicate that kinetic energy has an influence on the Janssen effect (Duri et al. 2018). In order to revisit the Janssen effect, experiments and Discrete Element Method (DEM) simulations are compared to investigate the structure of an ensiled granular medium poured in a cell by a single point at different initial drop heights and flow rates (parameters which allow to control kinetic energy).
A population of glass beads of 1 to 2 mm diameter with a small span value (50/50 in volume) is poured in an open glass cell container made of transparent glass walls. A flat steel probe is used to simulate the bottom of the cell and allows the measurement of the applied vertical stress, as in Janssen's experiment (Janssen, 1895). The probe is screwed on a rod that is linked to a load cell of a texture analyser (TA.XT2, Table Micro System), which is used as a force sensor. The filling is provided by a funnel and the flow rate is modulated by the output diameter.

*Speaker

An ”own homemade code” in c++using DEM is developed to calculate the force network of a similar ensiled granular medium under gravity. A code using the coarse-graining method (Weinhart and Luding, 2016) is used determinate the stress fields of the stress tensor and a new method which using two grids in order to increase the accurate is developed to determine the compactness field. With these three codes we can now explore all the contacts between the particles by the calculus of (i) normal and tangential forces, (ii) moment, (iii) mobility, of each particle.

DEM simulations show that in all cases tested, the compactness is relatively uniform. We observe the presence of a layer at the upper part of the particle bed, in which the stress is generally assimilated to a ”quasi-hydrostatic” state. Under this first layer, Janssen's hypothesis that stresses are lateral uniformity is not valid: there is a strong local heterogeneity of the stress within the granular medium. It can be observed that the redirection coefficient defined by Janssen (Janssen, 1985) ratio between lateral stress and vertical stress, is not constant. Indeed, after each filling, the sliding threshold is not realized for all grains located on the wall. It is necessary to lower the bottom to activate the contacts. Experiments show that (i) the Janssen' law doesn't describe the vertical stress profile which is not saturated without activation of the contacts at the wall, (ii) the vertical stress profile depends on rate of filling, and (iii) the profile is also defining in dynamic conditions (this is not only a static profile). These results indicate that the Janssen effect has a dynamic nature largely due to the filling conditions and the restitution properties of grains. When wall slippage is not achieved, there is no vertical stress saturation even if the edge effect leads to a gradual decrease in vertical stress.
These experimental and numerical approaches redefine the mechanical equilibrium conditions of a grain column by invalidating the three major assumptions of Janssen's model. A new heuristic model is purposed. Its employs a parameter that can be defined from the structural description obtained by DEM simulations.

Keywords: ensiled granular medium, Janssen effect, Discrete Element Method, coarse graining