A dynamic Janssen effect

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Abstract

When granular materials are stored in a container, a part of the weight of the grains is reported to the container walls through arch-forming oblique force chains and wall friction. This effect, well-known in the storage industry, is called the Janssen effect and was discovered in 1895. It is more pronounced when the container gets taller compared to its horizontal dimensions, and can eventually lead to container failure if not properly accounted for. Its physics are nevertheless well-understood, and rely on a limited number of parameters, in addition to the container geometry: a so-called Janssen coefficient (defining the ratio between vertical and horizontal stress in the granular medium), and a wall-grain friction coefficient. However, this theory is based on the assumptions of a granular material at rest and of a fixed container. There are situations, however, where these assumptions are no longer valid, for example in the case of pneumatic transport of grains in a pipe. In this communication, we investigate the consequences of a vertical (i.e. downwards or upwards) motion of the granular sample inside an infinitely tall vertical container, caused by the piston-like motion of its lower plate (the walls remaining fixed). We perform 2D DEM simulations and vary in a systematic way the friction coefficients (intergranular, and with the container walls), the quantity of granular matter, and the direction and the velocity of the vertical motion.

By doing so, we illustrate the complexity of this situation, by identifying several regimes adopted by the granular mass to accommodate these boundary conditions: wall-sliding, wall-rotation, stick-slip, convection, intermittence, fluidization, etc. We show that a Janssen-like formulation can be empirically retrieved based on these simulations, but with parameters that strongly depend on the regime and on the model parameters.
We will also discuss experimental observations of a millifluidic granular slug displacement in the light of the numerical simulations performed. Despite some strong differences between the numerical simulation of a two-dimensional granular material confined inbetween moving vertical walls, and the experimental displacement of a small volume of glass beads immersed in water in vertical millifluidic tube, strong analogies can be put in evidence. A transition in the granular slug displacement regime is observed when the speed increases. With the help of the numerical parameter study some interpretation of the experimental observation will be exposed.

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