Collisional regime during the discharge of a 2D silo

Roberto Arévalo[1]
[1]Research Centre for Energy Resources and Consumption (CIRCE)
Industrial Park Dinamiza, Ranillas Ave. 3D, 1st floor 50018, Zaragoza (Spain)

A humble silo quietly discharging by gravity is a deceptively simple system that has been a benchmark for granular flow investigations for many years. An striking characteristic of the silo is that the flow can be spontaneously arrested when the exit is still as big as 4 or 5 grain diameters [1]. An arch in $2D$ or a dome in $3D$ is formed that blocks the flow.

The question of whether exists a definite orifice size separating the flowing and jammed states naturally arises. The matter has been extensively studied by means of experiments in $3D$ and $2D$. Studying the size of the avalanches as a function of the exit size one could in principle extrapolate the critical size for which the avalanche would be infinite, *i.e.*, the flow would be continuous. However, these measurements are rather difficult to carry out due to the fast growth of the avalanches of grains. As a consequence, the data can be fitted equally well to functions which present a critical value and to functions that do not. By other side, the critical exponent and the value of the critical outlet size in $2D$ turns out to be rather large to be easily interpretable. In the literature one can find opinions in favor and against the existence of a critical outlet size. In the latter case, a blocking arch can always develop but the probability decreases upon increasing the outlet size until it is unobservable whithin experimental time windows.

Looking closely at the bed of grains in the silo one can see that there are two very different regions. In the bulk of the silo grains are in permanent contact, so continuous approximations are able to yield results for velocity distributions or mass flow. Close to the exit, however, the density of the medium decreases and contacts are instantaneous. Thus, the collisional nature of the dynamics becomes significant, warranting a dedicated investigation as carried out in this work. More interesting, the vicinity of the outlet is the region where the arches that block the flow for small apertures are formed.

The present work [2] reports a novel investigation into the collisional dynamics of particles in the vicinity of the outlet of a *2D* silo using molecular dynamics simulations. It is found that the transition from the clogging regime (at small apertures) to the continuous flow regime is smooth in collisional variables. An example of this is shown in Fig. 1 where the normalized collision frequency is plotted against the aperture size. The collision frequency grows with the orifice size for small orifices until it reaches a saturating value. The transition is smooth with no hint of critical behavior. The variation of the collision frequency closely follows that of the packing fraction of the medium in the same window of observation around the orifice. This suggests a connection between the packing fraction and the probability of arch formation.

An alternative look at the collision frequency is the time between collisions or time lag. This variable also shows a smooth transition, decreasing upon increasing the size of the exit down to a saturating value. The distribution of time lags tends to a power law.

Besides the collisions frequency, the histograms of the velocities of individual particles are also studied. The horizontal histograms are gaussian, as expected, for all sizes of the exit. The histograms of the vertical velocity are nearly gaussian. The small deviations arise from the difficulty of removing the bulk velocity, which is not constant inside the observation window. However, the important observation is that these histograms are also unaffected by the transition from the clogging to the continuous flow regime and fall on top of each other when normalized. Finally, even the fluctuations of the flow around the average are observed to be gaussian for all apertures.

Our conclusion is that the collisional dynamics of particles does not show evidence of critical behaviour respect to the outlet size. Furthermore, it is worth noting that the change of behaviour (the transition to a plateau) of the collision frequency and the time lag occur at a value of D larger than that for which arches start to appear. It is difficult to harmonise this observation with the existence of a critical D which separates the continuous flow regime from the clogging regime. It is consistent, instead, with a gradual decrease in the probability to observe clogs as the size of the outlet increases.

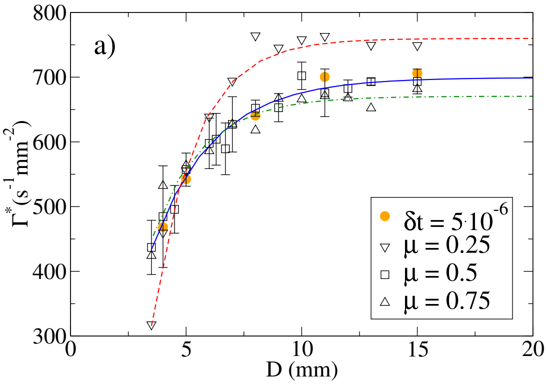

Fig. 1. Normalised collision frequency as a function of the outlet size. The empty symbols represent the main result, while the orange circles are the checking values obtained reducing the integration time step of the simulations and $\mu = 0.5$.

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[1] I. Zuriguel, *Clogging of granular materials in bottlenecks*, Papers in Physics **6**, 060014 (2014).

[2] R. Arévalo, *Collisional regime during the discharge of a 2D silo*, to appear in Phys. Rev. E `https://arxiv.org/abs/2202.08586`