Role of dynamics in silo clogging

Diego Gella[1], Diego Maza[1] and Iker Zuriguel[1]

[1] Departamento de Física y Matemática Aplicada, Facultad de Ciencias, Universidad de Navarra, E-31080 Pamplona, Spain.

When a silo filled by grains is unloaded through an orifice few times larger than the typical particle size, the flow might be arrested due to the formation of arches. The rate of clogging is often quantified by means of the avalanche size s i.e. the number of beads discharged between two clogs. The distribution n_R of this variable follows a exponential decay, which is described by means of a probabilistic model based on a unidimensional percolation [1]:

$$n_R(s) = (1 - p_R)p_R^s \tag{1}$$

where p_R is the probability that a bead passes through an orifice of size R, and it is directly related to the mean avalanche size as $\langle s \rangle = \frac{p_R}{1-p_R}$. The nature of the dependence of p_R on R is not clear. In fact, according to K. To [2], the mean avalanche size $\langle s \rangle$, can be fitted by means of a power law as well as of a quadratic exponential. The main difference between them is that, unlike the latter, the first equation involves the existence of a critical size of orifice above which clogs never happen. Some models, based on the geometric features of the system, have been developed in order to give physical support to the quadratic exponential [3, 4]. However, the role of dynamics in clogging has been gone almost unnoticed over the years. Indeed, for the development of a stable arch two conditions must be fulfilled: the beads must be placed in the appropriate location and they must resist the energy dissipation of the particles above.

Up to now, the studies related to this field have account for silos discharged exclusively by gravity. Only the numeric works of R. Arévalo et al. [5, 6] have dealt with the influence of the driving force in clogging. Therein, they computed the avalanche size distributions for different values of gravity and found an increasing but weak dependence of $\langle s \rangle$ on g. Also, a quasi-static value for the mean avalanche size was achieved in the limit of zero gravity.

The aim of this work has been to experimentally study this question from a different perspective. The setup consists on a quasi-2D and transparent silo filled by 4 mm diameter beads of stainless steel. Instead of altering gravity, a conveyor belt has been placed just under the exit to control conveniently the outflow rate of material. The automatized measurement process is able to detect and break the clogs and register the avalanche sizes by means of a balance. Keeping the hole size fixed, we have obtained distributions of avalanche sizes for several values of the conveyor belt velocity v_b. An exponential decay behavior has been recovered when implementing the experimental probability density function (PDF) for two different values of v_b as shown in fig 1. Furthermore, the mean avalanche size has revealed a dependence on the grains velocity remarkably stronger than the one obtained in [5, 6].

Finally, we expect to relate this behavior to some dynamic

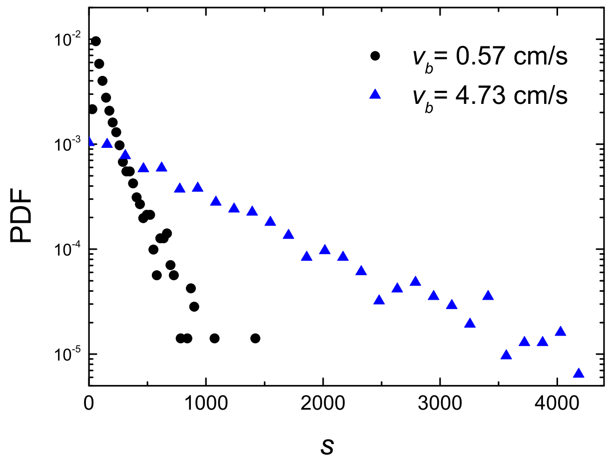

Figure 1: Experimental Probability Density Function (PDF) of the avalanche size s for two values of the extraction velocity v_b of a conveyor belt as indicated in the legend. Note the logarithmic scale in the vertical axis.

variables such as packing fraction, velocity or kinetic stress fields. To this end, with the help of a high speed camera, we are recording and processing videos of the outlet region while the material is flowing, that is, in the time between two clogs.

[1] I. Zuriguel, L.A. Pugnaloni, A. Garcimartín and D. Maza, Phys. Rev. E **68** 030301(R) (2003).

[2] K. To, Phys, Rev, E **71** 060301(R) (2005).

[3] A. Janda, *Análisis experimental del proceso de descarga de medios granulares*, (PhD Thesis, Pamplona, 2010).

[4] C. C. Thomas and D.J. Durian, Phys. Rev. Lett. **114**, 1781001 (2015).

[5] R. Arévalo, I. Zuriguel, D. Maza and A. Garcimartín, Phys. Rev. Lett. **89**, 042205 (2014).

[6] R. Arévalo and I. Zuriguel, Soft Matt. **12**, 123 (2016).