Granular flow through an orifice: solving the free fall arch paradox

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ABSTRACT

Several theoretical predictions of the mass flow rate of granular flows through outlets are based on the existence of a free fall arch region covering the silo outlet. Early in the nineteenth century, it was suggested that the particles crossing this region lose their kinetic energy and start to fall freely under their own weight. However, there is not conclusive evidence of this hypothetical region. We examined experimentally and numerically the micro-mechanical details of the particle flow through an orifice placed at the bottom of a silo. Remarkably, the contact stress monotonously decreases when the particles approach to the exit and it only vanishes just at the outlet. The behavior of this magnitude was practically independent of the size of orifice indicating that particle deformation is insensible to the size of the aperture. Contrary, the behavior of the kinetic stress puts on evidence that the outlet size controls the propagation of the velocity fluctuations inside the silo. Examining this magnitude, we conclusively argue that indeed there is a well-defined transition region where the particle flow changes its nature. Above this region, the particle motion is completely correlated with the macroscopic flow. Our outcomes clarify why the free fall arch picture has served as an approximation to describe the flow rate in the discharge of silos.

REFERENCES

[1] S. M. Rubio-Largo, A. Janda, D. Maza, I. Zuriguel, and R. C. Hidalgo "Disentangling the Free-Fall Arch Paradox in Silo Discharge" *Phys. Rev. Lett.,* **114,** 238002, (2015).