Unexpected segregation patterns in high speed granular flows

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Classically, for free surface flows of binary granular mixture, large particles migrate at the top of the flow while small ones percolate to the bottom. The key mechanisms at the origin of this segregation behavior have been identified as a combination of squeeze expulsion and kinetic sieving (Savage & Lun J. Fluid Mech. 1988). In this case, the segregation process is governed by the gravity. We discovered here by means of numerical simulations a new segregation pattern in high speed granular flows where size segregation is driven mostly by granular temperature gradients rather than gravity, which highlight the complexity of providing a complete description of segregation processes.

High speed granular flows are obtained by means of discrete numerical simulations (DEM) in a confined geometry with lateral frictional side-walls. Recently, Brodu et al. (Phys. Rev. E 2013, J. Fluid Mech. 2015) highlighted that this confined geometry allows to produce steady and fully-developed flows at relatively high angles of inclination, including a rich and broad variety of new regimes. In particular, they showed the existence of supported regimes, characterized by a dense and cold (in terms of granular temperature) core floating over a dilute and highly agitated layer of grains, accompanied with longitudinal convection rolls.

We performed extensive numerical simulations within this geometry with binary mixture of spheres with a given size ratio of 2. We analyzed segregation patterns of steady and fully-developed flows for inclination angles ranging from 18° to 50° and various mixture proportions of large particles ranging from 0 to 100%. We evidenced a new segregation pattern that emerge in the supported flow regimes: large particles no longer accumulate in the upper layers of the flow but are trapped in the dense core and localized at the center of the convection rolls. The strong temperature gradients that develop between the dense core and the surrounding dilute layer seem to govern the segregation mechanism. The accumulation of large particles in the dense core, which is the fastest region of the flow, also tends to enhance the total mass flux in comparison with similar mono-disperse flows.