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# Segregation in sheared granular flows: forces on a single coarse particle

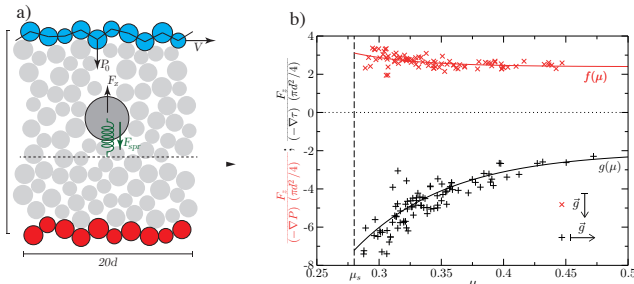
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**Abstract.** In order to better understand the mechanism governing segregation in granular flows, the force experienced by a large particle embedded in a granular flow made of small particles is studied using discrete numerical simulations. An empirical expression of the segregation force is proposed as a function of the stress distribution.

A rich phenomenology is observed in flows of polydispersed granular material. When flowing, large and small particles have a tendency to migrate in different regions. Important progresses have been made for describing polydispersed granular flows, and a framework based on a mixture theory has been developed [1–3]. However, the segregation flux in those models remains empirical and would benefit from a better understanding of the segregation phenomenon. The objective of the present numerical study is to study the case of a single coarse particle in a bath of small particles, to understand the forces experienced by the coarse particle [4].



**Figure 1.** a) Sketch of the configuration: a coarse particle is vertically trapped in an harmonic potential; b) rescaled segregation force as a function of  $\mu = \tau/P$  for a vertical and horizontal gravity.

The configuration of interest is sketched in Fig 1a. A 2D granular medium of size  $d_s$  is sheared between two rigid rough plates under a confining pressure  $P_0$  and in presence of gravity. The discrete element simulations are made using the open source software LIGGGHTS.30. To study segregation, a particle of diameter  $d_c$  larger than  $d_s$  is introduced in the layer. To accurately measure the force experienced by the test particle, we mimic the existence of an optical trap. The coarse particle is attached with a spring to the vertical position, but is free to move horizon-

tally. When the stationary regime is reached, the coarse particle flows with the bulk but remains in average at the same altitude, which directly gives access to the segregation lift force  $F_z$ .

A large number of simulations have been carried out and the segregation force  $F_z$  has been measured for different confining pressure  $P_0$ , different shear velocity  $V$ , different position in the layer  $z_0$ , different coarse particle size ( $d_c$ ) and different gravity conditions. We have shown that depending on the stress gradient, the segregation force can change sign (Fig. 1b), but that a simple scaling law can be proposed for the segregation force as a function of the normal and shear stress distribution  $P(z)$  and  $\tau(z)$  in the shear flow:

$$F_z = -\pi \frac{d^2}{4} a(d_l/d_s) \left( -f(\mu) \frac{\partial P}{\partial z} + g(\mu) \frac{\partial |\tau|}{\partial z} \right),$$

with  $\mu = \tau/P$ ,  $f(\mu)$ ,  $g(\mu)$  and  $a(d_l/d_s)$  being functions that we have measured, Such an expression may be useful when introduced in recent models for polydispersed flows. However, more studies are needed to better understand the physical origin of the measured segregation force.

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