Immersing in a rigid particle flow versus immersing in a soft particle flow

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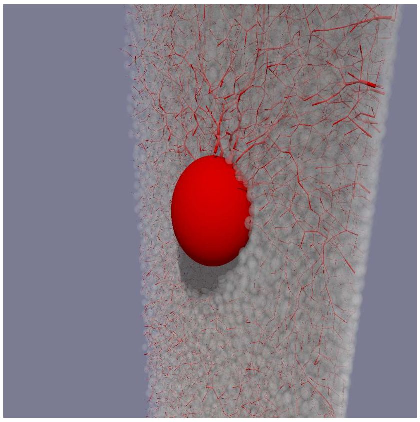
In this work, we have shown that a sphere suspended in a discharging silo experiences mechanical forces from the weight of the overlaying layers and the friction of the surrounding moving granular material. In experiments and simulations with hard frictional glass particles, the force on the obstacle was nearly uninfluenced by the flow velocity. Its value remained unaltered during a large part of the discharge process and depended linearly on the obstacle diameter. The simulations indicate that during the discharge, the pressure of the granular bed at the obstacle's surface scales with the size as $p(z') \sim 1/R$, which is congruent with a force proportional to the diameter of the obstacle. Besides, the mean pressure gradient acting on the obstacles was practically the same for all the explored orifices and did not vary significantly in the discharge process. It is worth mentioning that when the outflow of GLS was interrupted, the force on the ball remained nearly unchanged, indicating the predominantly static nature of the interaction. On the other hand, in flowing frictionless soft particles, noticeable drag is added to the gravitational forces on the suspended obstacles. As confirmed by our micromechanical analysis, the obstacle experienced a total force from the top as if immersed in a dynamic hydrostatic pressure profile, but practically without acting from below. Irrespective of the low friction, the particle collisions generate a noticeable drag force. It increases with velocity up to a certain speed, but then reaches saturation. We argue that at high discharge rates, the local packing density drops, thus reducing the drag force and compensating for the effects of increased velocity.

a)



b)

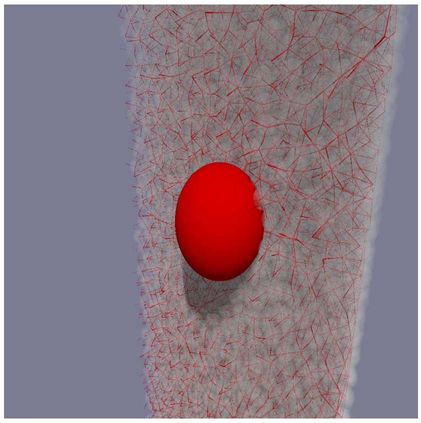


Fig. 1. Force nextwork acting on an obstacle with 40 mm diameter submerged in GLS (a) and in HGS (b)