

Impact of inertia on flow-induced particle motion in laminar shear flow

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The onset of particle motion is a phenomenon with critical implications for various natural and industrial processes. It is important for sediment transport in rivers and on shores, bed erosion, the formation of ripples and dunes, filtration processes, cleaning surfaces, pneumatic conveying, particle assembly for meta-materials and cell detachment.

While most studies focus on turbulent flow and highly disordered substrates, we study the onset of particle motion in laminar flow and a well-arranged substrate. As a continuation to previous studies in creeping flow conditions^{1,2,3}, we study the impact of inertia. To that end, we built an experimental setup composed of a conveyor belt located in a temperature-controlled tank filled with silicone oil. At the bottom, we placed a substrate of 20,000 steel spheres with a diameter of 5 mm in a quadratic arrangement. By running the belt, we induce a Couette flow between the lower side of the conveyor belt and the substrate, on which we place a single mobile bead. The movement of the bead is tracked with a camera. For characterizing the onset of particle motion, we use the Shields number, defined as the ration of the flow induced friction force to the effective particle weight:

$$\theta = \frac{\mu \dot{\gamma}}{\left(\frac{\rho_p}{\rho_f} - 1\right) g D_p}$$

Equation 1: Shields number where τ is the shear stress, ρ_p the particle density, ρ_f the fluid density, g the acceleration of gravity, D_p the diameter of the single particle, μ the kinematic viscosity of the silicone oil and $\dot{\gamma}$ the shear rate created by the ratio of the belt velocity and the gap width

As influencing parameters, we vary the gap height, belt velocity, particle density, kinematic viscosity, and bead diameter. To change the particle density, we use beads of different materials like polyamide 6.6, polyoxymethylene, soda-lime glass, silicon nitride and aluminium oxide. Changing the bead diameter allows studying the influence of the surface roughness, which causes different levels of shielding and different angles of repose. Here we present our findings regarding the onset of particle motion being able to increase the parameter range of the particle Reynolds number by one order of magnitude compared to previous studies. We also present our results for tracking the particle motion at supercritical Shields numbers and analysing in which way the particles move like rolling, sliding, jumping etc.

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¹Agudo and Wierschem, *Phys. Fluids* 24, 093302 (2012)

²Agudo et al., *Phys. Fluids* 26, 053303 (2014)

³Topic et al., *Phys. Fluids* 31, 063305 (2019)