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Dilation and flow resistance of granular flows in a rotating drum

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The flow resistance in granular mass flows can be due to frictional contacts or collisional interactions between particles. For a constant number of particles, the transition from a frictional to a collisional regime is expected to depend on flow velocity and is associated with an increase of volume and a decrease of bulk density, an effect termed dilation. The relation between velocity, dilation and flow resistance is not well understood. Here we present results of steady, non-uniform flows of ceramic beads (d = 4 mm) in a rotating drum, a setup allowing observations and averaging of parameters measured over an extended period of time. We systematically varied flow mass between 12.3 and 49 kg and flow velocity between 0.2 and 1.2 m/s, while continuously measuring basal normal stress and flow depth. Flow resistance was assessed by calculating average bulk shear stress from torque measurements at the axis of the drum as well as from the deviation of the center of mass from the vertical. Additionally, the flows were captured by high-speed video recordings through the transparent side wall. We find bulk densities at the deepest section of the flow decreasing from 1430 kg/m³ at low velocities to 1370 kg/m³ at the highest velocity for the largest flow mass. At the same time flow resistance increased linearly. When the flow mass was reduced, also bulk density decreased, indicating the importance of overburden pressure for dilation. Video recordings revealed that shear is concentrated in depth zones of lower volume fraction. Our results shall contribute to a better understanding of the transition from a frictional to a collisional flow regime and may help to assess the importance of dilation for gravitational mass flows.