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Experimental study on the effects of fixed boundaries in channelized free surface dry granular flows

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The dynamics of granular mixtures, involved in geophysical flows like avalanches and debris flows, is far from being completely understood. Several features of their motion, such as rheological stratification, non-local and boundary effects, still represent open problems. Experimental investigations at laboratory scale are an important tool that can provide insights about the dynamics of gravity driven granular flows. The measuring techniques should be non-invasive in order to measure undisturbed flows.
In this work we present an experimental campaign devoted to the measurement of the velocity profiles of free surface steady granular flows in an open channel. To achieve this goal the flows were recorded by two cameras and velocity profiles were obtained by image analysis.
The employed granular medium consists of acetal-polymeric beads with a mean diameter of 3mm and an estimated internal friction angle of 27°. All the experiments have been performed in a 2m-long plexiglas flume with a rectangular cross-section and a slope angle of 30°. The upper part of the channel was used as a reservoir where the material was loaded before each run and then let flow down through an adjustable gate. Several mass flow rates were investigated. Three different basal surfaces were employed so as to observe slip and non-slip boundary conditions: a smooth Bakelite surface, a roughened surface, obtained by gluing a layer of grains on the bed surface and a sandpaper surface with characteristic length of the roughness equal to 425 μm. The flume is equipped with two high-speed cameras, one placed aside the channel and the other one perpendicular to the channel bed, as to get both side-wall and free surface velocity profiles. The particle image velocimetry open-source code, PIVlab, is employed for estimating the flow velocities.
All the free surface velocity profiles show an approximately parabolic shape with a maximum at the cross-section midpoint and a minimum at the side-walls, due to the wall friction.
Different kinds of side-wall velocity profiles are observed. As regards the smooth basal surface, a slip velocity at the bed is observed. The profiles are Bagnold-type near the free surface and become linear as the depth increases. On the glued-grain basal surface the flow velocity at the bed is null and all the velocity profiles show a rheological stratification with a lower exponential tail and an upper linear profile. Grain rolling is observed at the sandpaper bed, instead. With the increase of flow depths, the velocity profiles gradually shift from the ones observed on the smooth bed to the ones observed on the glued-grain bed.
In order to further understand the constitutive behaviour of granular mixtures, it is useful to perform simultaneous measurements of flow velocity and volume fraction. In this perspective, a new series of experiments is actually undergoing for the measurement of the volume fraction.