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The streamwise solid volume fraction of parallel accelerating dry granular flows and the evolution of the fraction across normal granular shocks

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We develop a pseudo three-dimensional optical method to measure the solid fraction of granular flows down an inclined rectangular chute. The chute, made of smooth transparent plexiglass, is 5 cm wide and 150 cm long with adjustable inclination. The granular material is glass beads at nominal diameter 4 mm. The internal friction angle is 34° measured by the standard Jenike shear tester and the friction angle between the beads and the plexiglass wall is 15°.

The key of the measuring technique is to reconstruct the solid volume fraction using simultaneous measurements of three optically observable surface/boundary fields of the flow. These fields are the top free surface, the basal surface and one side boundary. The measured physical quantities include the flow depth and velocity. Optical corrections are performed and a linear interpolation scheme is proposed to calculate the solid volume fraction. The method is verified to be robust.

Two flow conditions are illustrated. The first is a parallel accelerating flow. Four inclination angles, from 27° to 36° at 3° intervals are tested. This range of angle overlaps the internal friction angle of the glass beads. Two distinct groups of streamwise dependence of the solid fractions are found. They are separated by an inclination angle agreeing with the internal friction angle. For the two smaller inclination angles, the solid fractions are streamwisely a linear function whilst for the other larger inclination, the fractions have a nonlinear concave shape. They all decrease towards the downstream direction.

The other flow condition is the same chute flow but with a normal granular shock. The shock is produced by a fixed semi-circular cylindrical obstacle transversally aligned at the middle of the sliding chute. It is found that the perturbation caused by the basal surface bump back-propagates into the upstream for a certain distance. As result, the solid fraction increases and reaches a maximum value as approaching the bump, and then becomes decreasing while passing over the obstacle. The trend of flow expansion (the decreasing of the solid volume fraction) continues to the downstream of the obstacle as the flow volume continues to grow. Eventually, the gravity regains its dominance and the flow restores into parallel. The effects of the inclination angle and the size of the bump are commented.