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Kinematics of entrainment and deposition of granular material in turbulent flows

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The work herein presented concerns a cohesionless granular bed subjected to a turbulent open-channel flow. We aim to clarify the kinematics of entrainment and deposition of individual sediment particles. In particular, we quantify a) the turbulent flow field in the vicinity of particles at the instants of their entrainment and of their deposition; b) the initial particle velocity and the particle velocity immediately before returning to rest. The experimental work was performed at the Hydraulics Laboratory of IST-UL in a 12:5 m long, 0:405 m wide glass-walled flume recirculating water and sediment through independent circuits. The granular bed was a 4:0 m long and 2:5 cm deep reach filled with approximately spherical glass beads (5 mm diameter) packed to a void fraction of 0:356. Laboratory tests were run under conditions of weak beadload transport with Shields parameters in the range 0:007 to 0:03. Froude numbers ranged from 0:63 to 0:95 while boundary Reynolds numbers were in the range 130 to 300.
The option for artificial sediment allowed for a simplified description of particle positioning at the instant of entrainment. In particular support and pivoting angles are found analytically. Skin friction angles were determined experimentally as well as exposure, defined as the ratio of the actual frontal projection of the exposed area to the area of a circle with 5 mm diameter, and protrusion, defined as the vertical distance between the apex of the particle and the mean local bed elevation.
Flow velocities were acquired with 2-component PIV and Vectrino-ADV. The former allowed for the spatial definition of the flow field around the particle with a temporal resolution of 15 Hz and the latter allowed for the collection of time series of 3 velocity components in the close vicinity of the particle with a temporal sampling rate of 50 Hz. Velocity measurements were grouped by categories of exposure and protrusion. The flow velocity in front of the particle, u, at the instant of entrainment are generally in accordance with a theoretical model of (FHB2015). It was also found that the flow velocities and the particle velocities at the instant of deposition were poorly correlated. Furthermore, preliminary results seem to indicate that the probability density function (pdf) of particle velocities just before returning to rest is similar to that of unconstrained moving particles.

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