Standing jumps formed in shallow granular flows down smooth inclines

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ABSTRACT

Granular materials are ubiquitous in natural geophysical flows, such as rock avalanches, snow avalanches and landslides, as well as in many industrial processes involving the transport of particles. We performed laboratory tests on shallow granular flows down a smooth chute and on the shape of the standing jumps formed in those flows when a gate partially obstructs the chute exit.

We studied how the velocity profiles measured at the sidewalls, the chute base and the free surface of the flows change with slope and the amount of mass discharge. It is experimentally confirmed that the flows on the smooth base can be seen as Bagnold-like sheared flows over an effective bumpy base made of the basal sliding layer, as previously shown by discrete element simulations [1]. We analysed the lengths and shapes of the discontinuities in height and velocity when a gate obstructs the chute exit, and thus revealed a rich variety of standing jump patterns. Diffuse jumps can occur when the Froude number is below a critical value, in contrast to steep jumps formed in rapid granular flows at higher Froude numbers. Our study reveals that the traditional shock equation strictly valid for incompressible frictional fluids fails in describing the thickness of the diffuse frictional jumps. This result motivated us to propose a full jump equation that accounts for the forces acting in the control-volume surrounding the wave, namely the weight of the jump and the effective friction force, in light of the earlier work by Savage [2], recently revisited and extended by Faug [3]. The full equation proposed is then in contrast with the spirit of the traditional shock equation for which the control-volume is assumed to shrink onto a singular surface (shock as a mathematical abstraction).

We will show that the full jump equation compared to our laboratory data on the geometry of the jumps allows us to derive the one-to-one relation between the effective basal friction and the inertial number [4], in a similar fashion that was initially used to establish the depth-averaged friction law for granular flows down inclines [5]. Additional research should address the details of the local stress state and the shear-strain inside the jump in order to further analyse those results.

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