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Pattern formation of granular avalanches simulated by particle method with hydrodynamics interaction

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Avalanches, generally taken as a class of massive landslide phenomena, cover gravity currents and density currents, for instance, snow avalanches, debris flows, and pyroclastic flows. These flows migrate downward as a mixture of solid and fluid and form common structures, one of which is termed as the head-tail structure. Concretely, at the moving front of avalanche, a large head is formed by gathering the large materials, whereas at the rear end, an elongated tail is formed by leaving behind the smaller materials. As a factor for the formation of head-tail structure, the ratio of the air drag to the gravity is considered most relevant. For example, a granular flow consisting of the light particles like the polystyrene forms the head-tail structure as well as the wavy pattern with many heads at the moving front of avalanche [1]. In contrast, experiments using heavy particles (air drag $<<$ gravity) like the glass beads do not generate the head-tail structure although they form wavy pattern similar to ones using light particles [2]. Additionally, the experiment using light particles shows that the head size increase with the increasing particle radius. To explain these facts, several models have recently been proposed; the fluid flow model assumes an avalanching body as a mass of fluid, the mass center model assumes an avalanche as a huge particle, and so on [3, 4]. However, the materials constituting avalanches are granular materials such as polystyrene or glass beads and are definitely not fluid. Moreover, the interaction between particles may play a nontrivial role, which is out of the scope of fluid model and one particle model. The following our models are proposed to overcome the above shortage of previous models.

This model is roughly based on three basic assumptions; First, the granular consisting of spherical (three-dimensional) particles only moves along two-dimensional surface. Second, only the translational motion of particles is considered, whereas the rotational motion of particles is ignored. Third, as the force acting on the particle, we considered three types; (i) gravity as the dominant driving force of avalanche, (ii) repelling force between particles which causes the excluding volume effect, and (iii) drag force by fluid.

Numerical simulations using this model are conducted on a slope with a constant inclination angle. As initial conditions, we use 2000 particles and two different setup; i) circular and ii) linear. Simulations using i) show the formation of a single head and the vortex convection inside the avalanche independent of the particle radius, whereas an increasing in the particle radius enhances an effect to pull the rear particles forward. On the other hand, simulations using ii) show that the air drag destabilizes the initial straight front of avalanche to deform into a wavy pattern with many heads. In addition, the width of head increases with the number of particles constituting a head and gives a linear relation ship with the particle radius.

References

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