A two-phase solid/fluid model for dense granular flows including dilatancy effects

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We present a two-phase two-thin-layer model for fluidized debris flows that takes into account dilatancy effects. It describes the velocity of both the solid and the fluid phases, the compression/dilatation of the granular media and its interaction with the pore fluid pressure [*Bouchut et al.*, 2016].
The model is derived from a 3D two-phase model proposed by *Jackson* [2000] based on the 4 equations of mass and momentum conservation within the two phases. This system has 5 unknowns: the solid and fluid velocities, the solid and fluid pressures and the solid volume fraction. As a result, an additional equation inside the mixture is necessary to close the system. We propose here an approach to correctly deal with the thermodynamics of Jackson's model by closing the mixture equations by a weak compressibility relation following *Roux and Radjai*, 1998. This relation implies that the occurrence of dilation or contraction of the granular material in the model depends on whether the solid volume fraction is respectively higher or lower than a critical value. When dilation occurs, the fluid is sucked into the granular material, the pore pressure decreases and the friction force on the granular phase increases. On the contrary, in the case of contraction, the fluid is expelled from the mixture, the pore pressure increases and the friction force diminishes. To account for this transfer of fluid into and out of the mixture, a two-layer model is proposed with a fluid layer on top of the two-phase mixture layer.
Mass and momentum conservation are satisfied for the two phases, and mass and momentum are transferred between the two layers. A thin-layer approximation is used to derive average equations. Special attention is paid to the drag friction terms that are responsible for the transfer of momentum between the two phases and for the appearance of an excess pore pressure with respect to the hydrostatic pressure. We obtain a depth-averaged model with a dissipative energy balance in accordance with the corresponding 3D initial system.
We present several numerical tests of two-phase granular flows over sloping topography that are compared to the results of other models. In particular, we quantify the role of the fluid and compression/dilatation processes in granular flow dynamics.

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