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Two-Phase Solid/Fluid Simulation of Dense Granular Flows With Dilatancy Effects

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Describing grain/fluid interaction in debris flows models is still an open and challenging issue with key impact on hazard assessment [1]. We present here 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 [2].

The model is derived from a 3D two-phase model proposed by Jackson [3] and the mixture equations are closed by a weak compressibility relation. 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 or a solid 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. Interestingly, when removing the role of water, our model reduces to a dry granular flow model including dilatancy.

We first compare experimental and numerical results of dilatant dry granular flows. Then, by quantitatively comparing the results of simulation and laboratory experiments on submerged granular flows, we show that our model contains the basic ingredients making it possible to reproduce the interaction between the granular and fluid phases through the change in pore fluid pressure. In particular, we analyse the different time scales in the model and their role in granular/fluid flow dynamics.

References

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