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A Two-Phase Solid/Fluid Model for Dense Granular Flows Including Dilatancy Effects

Anne Mangeney (1,2), Francois Bouchut (3), Enrique Fernandez-Nieto (4), and Gladys Narbona-Reina (4)

(1) University Paris Diderot, Institut de Physique du Globe de Paris, Sismologie, Paris, France (mangeney@ipgp.fr), (2) ANGE team, J-L-Lions-INRIA-CEREMA, Paris, France, (3) LAMA, University Marne la Vallée, France, (4) DMA, University of Seville, Spain

We propose a thin layer depth-averaged two-phase model to describe solid-fluid mixtures such as debris flows. It describes the velocity of the two phases, the compression/dilatation of the granular media and its interaction with the pore fluid pressure, that itself modifies the friction within the granular phase (Iverson et al., 2010).

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. Surprisingly, this issue is inadequately accounted for in the models that have been developed on the basis of Jackson's work (Bouchut et al., 2014). In particular, Pitman and Le replaced this closure simply by imposing an extra boundary condition at the surface of the flow. When making a shallow expansion, this condition can be considered as a closure condition. However, the corresponding model cannot account for a dissipative energy balance.

We propose here an approach to correctly deal with the thermodynamics of Jackson's equations. We close the mixture equations by a weak compressibility relation involving a critical density, or equivalently a critical pressure. Moreover, we relax one boundary condition, making it possible for the fluid to escape the granular media when compression of the granular mass occurs. Furthermore, we introduce second order terms in the equations making it possible to describe the evolution of the pore fluid pressure in response to the compression/dilatation of the granular mass without prescribing an extra ad-hoc equation for the pore pressure. We prove that the energy balance associated with this Jackson closure is dissipative, as well as its thin layer associated model. We present several numerical tests for the 1D case that are compared to the results of the model proposed by Pitman and Le.

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