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Complex yield criteria for three-dimensional granular flows

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The incompressible non-Newtonian Navier-Stokes equations have become a popular method for the simulation of granular flows [1, 2, 3]. The success of the $\mu(I)$-rheology [4] is certainly not insignificant for this. Within the framework of plasticity [5], this rheology can be described in terms of a yield surface and a flow rule. The yield surface is of Drucker-Prager type, parametrized with the inertial number I and the flow rule follows from incompressibility as von-Mises type.

However, the yield-strength of granular material depends on the loading type, e.g. plane strain shearing, triaxial extension or triaxial compression, which cannot be modelled with a Drucker-Prager yield criterion. Thus the Drucker-Prager yield criterion is no longer used in soil mechanics. The Mohr-Coloumb critrion or the Matsuoka-Nakai [6] criterion yield much more realistic results for the shearing failure of granular material. The difference to the Drucker-Prager criterion can be remarkable, especially if the loading type changes in time or space.

We demonstrate that the Drucker-Prager criterion within the $\mu(I)$-rheology can be easily replaced with an arbitrary yield surface, using the usual assumption of alignment between streching and deviatoric stress. We introduce the Matsuoka-Nakai yield criterion and thus obtain a rheology for granular flows that appropriately predicts different yield-strengths for different loading types. This rheology is, similar to the classic $\mu(I)$-rheology, fully compatible with the incompressible Navier-Stokes Equations and can be implemented into CFD frameworks such as OpenFOAM [7].

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References

[1] P.-Y. Lagrée, L. Staron, and S. Popinet, “The granular column collapse as a continuum: validity of a two-dimensional Navier–Stokes model with a μ(I)-rheology,” *Journal of Fluid Mechanics*, vol. 686, pp. 378–408, 2011.

[2] B. Domnik, S. P. Pudasaini, R. Katzenbach, and S. A. Miller, “Coupling of full two-dimensional and depth-averaged models for granular flows,” *Journal of Non-Newtonian Fluid Mechanics*, vol. 201, pp. 56–68, 2013.

[3] S. Savage, M. Babaei, and T. Dabros, “Modeling gravitational collapse of rectangular granular piles in air and water,” *Mechanics Research Communications*, vol. 56, pp. 1–10, 2014.

[4] P. Jop, Y. Forterre, and O. Pouliquen, “A constitutive law for dense granular flows,” *Nature*, vol. 441, no. 7094, p. 727, 2006.

[5] J. Lubliner, *Plasticity theory*. Courier Corporation, 2008.

[6] H. Matsuoka and T. Nakai, “Stress-deformation and strength characteristics of soil under three different principal stresses,” in *Proceedings of the Japan Society of Civil Engineers*, vol. 1974, pp. 59–70, Japan Society of Civil Engineers, 1974.

[7] H. G. Weller, G. Tabor, H. Jasak, and C. Fureby, “A tensorial approach to computational continuum mechanics using object-oriented techniques,” *Computers in physics*, vol. 12, no. 6, pp. 620–631, 1998.