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DEM simulation of granular flows in a centrifugal acceleration field

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The main purpose of mass-flow experimental models is abstracting distinctive features of natural granular flows, and allow its systematic study in the laboratory. In this process, particle size, space, time, and stress scales must be considered for the proper representation of specific phenomena [5]. One of the most challenging tasks in small scale models, is matching the range of stresses and strains among the particle and fluid media observed in a field event. Centrifuge modelling offers an alternative to upscale all gravity-driven processes, and it has been recently employed in the simulation of granular flows [1, 2, 3, 6, 7].

Centrifuge scaling principles are presented in Ref. [4], collecting a wide spectrum of static and dynamic models. However, for the case of kinematic processes, the non-uniformity of the centrifugal acceleration field plays a major role (i.e., Coriolis and inertial effects). In this work, we discuss a general formulation for the centrifugal acceleration field, implemented in a discrete element model framework (DEM), and validated with centrifuge experimental results.

Conventional DEM simulations relate the volumetric forces as a function of the gravitational force $\mathbf{G}_p = m_p\mathbf{g}$. However, in the local coordinate system of a rotating centrifuge model, the cylindrical centrifugal acceleration field needs to be included. In this rotating system, the centrifugal acceleration of a particle depends on the rotating speed of the centrifuge, as well as the position and speed of the particle in the rotating model. Therefore, we obtain the formulation of centrifugal acceleration field by coordinate transformation. The numerical model is validated with a series of centrifuge experiments of monodispersed glass beads, flowing down an inclined plane at different acceleration levels and slope angles. Further discussion leads to the numerical parameterization necessary for simulating equivalent granular flows under an augmented acceleration field. The premise of this validation is abstracting the role of the governing acceleration on the granular flow dynamics and extend it to a wider range of accelerations and slope angles. Based on this results we aim to validate the centrifuge scaling principle of flow velocity and flow height, and discuss the viability of centrifuge modelling of mass flows in a wider range of configurations.

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