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Bulbous head formation in bidispersed shallow granular flows over inclined planes

Irana Denissen, Thomas Weinhart, Stefan Luding, and Anthony Thornton
Universiteit Twente, Thermal and Fluid Engineering, Multiscale Mechanics, The Netherlands (i.f.c.denissen@utwente.nl)

Predicting the behaviour of hazardous natural granular flows (e.g. debris-flows and pyroclastic flows) is vital for an accurate assessment of the risks posed by such events. In these situations, an inversely graded vertical particle-size distribution develops, with larger particles on top of smaller particles. As the surface velocity of such flows is larger than the mean velocity, the larger material is then transported to the flow front. This creates a downstream size-segregation structure, resulting in a flow front composed purely of large particles, that are generally more frictional in geophysical flows. Thus, this segregation process reduces the mobility of the flow front, resulting in the formation of a so-called bulbous head.

One of the main challenges of simulating these hazardous natural granular flows is the enormous number of particles they contain, which makes discrete particle simulations too computationally expensive to be practically useful. Continuum methods are able to simulate the bulk flow- and segregation behaviour of such flows, but have to make averaging approximations that reduce the huge number of degrees of freedom to a few continuum fields. Small-scale periodic discrete particle simulations can be used to determine the material parameters needed for the continuum model.

In this presentation, we use a depth-averaged model to predict the flow profile for particulate chute flows, based on flow height, depth-averaged velocity and particle-size distribution [1], and show that the bulbous head structure naturally emerges from this model. The long-time behaviour of this solution of the depth-averaged continuum model converges to a novel travelling wave solution [2]. Furthermore, we validate this framework against computationally expensive 3D particle simulations, where we see surprisingly good agreement between both approaches, considering the approximations made in the continuum model. We conclude by showing that the travelling distance and height of a bidisperse granular avalanche can be well predicted by our continuum model.

REFERENCES

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