MSc project: What makes sand flow?

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Particulate materials are everywhere around us: sand, rice, coffee beans, powders in pharmaceutics, ground corn in animal feed, cement in building materials, etc. However, there is a lack of fundamental knowledge of how particulate materials behave, and we need this knowledge to be able to *predict* what we can do to engineer better. Such improvement is urgently needed, as mankind needs to do more with less to live more sustainably. But how can we reduce the waste resulting from making pharmaceutical pills? How can we improve the composition of concrete, the only material abundant enough to make enough houses?

One way of developing this fundamental knowledge is by doing Discrete Element Method (DEM) simulations, which simulates the motion of particles by applying external body forces (e.g. gravity, magnetic fields, etc) and particle interaction laws. This bottom-up approach has the potential to be very accurate, but it is also computationally expensive. Another way of understanding the behaviour of particulate materials is by looking at them on a “smoothed” scale: we capture the average behaviour of a number of grains in a “constitutive equation”, which can then be combined with the principles of mass and momentum conservation to form a continuum model. Solving continuum models is computationally much cheaper, but does not capture the microscopic details very well. In particular it cannot capture the role of “fluctuations”, the net result of many particle collisions, et cetera (see e.g. Figure 1).

In this project we aim to to understand the role of these fluctuations, by merging the two latest insights in continuum modeling and DEM simulations. The first one is that continuum modeling of particulate solids has shown that defining a constitutive equation based a “granular fluidity” field, with a diffusive component that captures the role of fluctuations, captures the material behaviour with great predictive accuracy. This diffusive component introduces a smoothing length-scale in the continuum models that depends on the local stress. Secondly, to obtain continuum properties from DEM simulations, one can “coarse grain” the discrete data with a smoothing function of a certain width. It seems reasonable to ask, whether the width of the smoothing function can be made dependent on the local stress, and thus allow us to calibrate a continuum model based on DEM simulations.

This is the question to be investigated in this Master project. You will get to know MercuryDPM, an open-source software for DEM simulations, and apply it to a suitable test case such as creep flow. You can then model the same system on the continuum level (using e.g. Matlab or Python). You will learn how to extract continuum quantities from the particle data and investigate how to match it with the continuum description. The result we hope for is a smoothing function for which the discrete and continuum descriptions match. The shape of this smoothing function will tell us how to predict similar situations with continuum modelling, without having to resort to costly DEM models or experimental measurements.

We are looking for a student *enthusiastic about investigating granular materials and computational modelling, ideally with some programming experience.*

If you are interested, please contact `t.weinhart@utwente.nl`; we look forward to working with you.

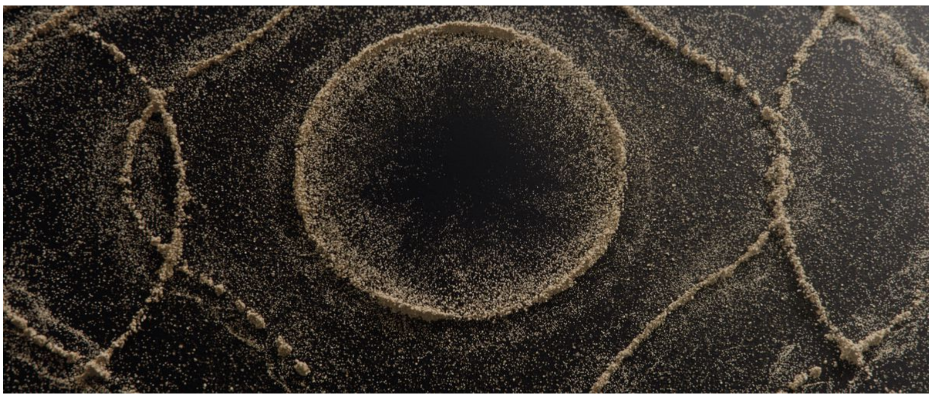

Figure 1: The Rings of Power opening sequence, showing diffusion caused by vibrations transmitted through the sand grains.