PHYSICAL MATHEMATICS SEMINAR

Size-dependent Continuum Modeling of Flowing Granular Media

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ABSTRACT:

Despite the ubiquity of granular matter in the world around us, the challenge of predicting the motion of a collection of flowing grains has proven to be a difficult one, from both computational and theoretical perspectives. Grain-by-grain discrete element methods can be used, but these approaches become computationally unrealistic for large bodies of material and long times. A broadly accurate continuum model would be ideal if it could be found, as it would provide a much more rapid means of calculating flows in real-world problems, such as those encountered in industrial design and geotechnical engineering.

With this challenge in mind, in this talk we propose a new constitutive relation for granular matter, which produces quantitatively accurate predictions for granular flow. The model is constructed in a step-by-step fashion. First we compose a local relation based on existing granular rheological approaches (i.e. the principle of "inertial" rheology) and point out where the model succeeds and where it does not. The clearest missing ingredient is shown to be the lack of an intrinsic length-scale. To tie flow features more carefully to the characteristic grain size, we justify a nonlocal modification which takes the form of a size-dependent term in the rheology (with one new material parameter). The nonlocal model is then numerically implemented with a custom-written User-Element in the Abaqus package, where it is shown to greatly improve flow predictions compared to the local model. In fact, it is the first model to accurately predict all features of flows in 'split-bottom cell' geometries, a decade-long open question in the field. In total, we will show that this new model, using three material parameters, quantitatively matches the flow and stress data from over 160 experiments in several different families of geometries. We close the talk by showing how the same model can be used to reconcile certain "strange" features of granular media that have been documented in the literature, such as the observation that thinner granular layers behave as if they are stronger, and the motion-induced "quicksand" effect wherein flow at one location reduces the yield limit everywhere.

TUESDAY, OCTOBER 14, 2014
2:30 PM
Building E17, Room 122

Reception following in Building E17, Room 401A
(Math Dept. Common Room)

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