MITMECHE

Colloquium

Mechanical Engineering Lecture in Mechanics

Modeling granular materials from fundamentals to applications: *Surprising complexity meets surprising simplicity*

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Granular materials are common in everyday life but are historically difficult to model. This has direct real-world ramifications owing to the prominent role granular media play in multiple industries and in terrain dynamics. One can attempt to track every grain with discrete particle methods, but realistic systems are often too large for this approach and a continuum model is desired. However, granular media display unusual behaviors that complicate the continuum treatment: they can behave like solid, flow like liquid, or separate into a "gas", and the rheology of the flowing state displays remarkable subtleties. To address these challenges, in this talk we develop a family of continuum models and solvers, permitting quantitative modeling capabilities for a variety of applications, ranging from general problems to specific techniques for problems of intrusion, impact, driving, and locomotion in grains.

To calculate flows in general cases, a rather significant nonlocal effect is evident, which is well-described with our recent nonlocal model accounting for grain cooperativity within the flow rule. On the other hand, to model only intrusion forces on submerged objects, we will show, and explain why, many of the experimentally observed results can be captured from a much simpler tension-free frictional plasticity model. This approach gives way to some surprisingly simple general tools, including the granular Resistive Force Theory, and a broad set of scaling laws inherent to the problem of granular locomotion. These scalings are validated experimentally and in discrete particle simulations suggesting a new down-scaled paradigm for granular locomotive design, on earth and beyond, to be used much like scaling laws in fluid mechanics.

We close with ongoing efforts expanding into wet granular flows, multi-scale approaches, and self-optimizing wheels for off-road traction.