MECHANICAL & INDUSTRIAL ENGINEERING COLLOQUIUM: ME 794

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224 MEC

Chaotic dynamics in granular flows from the Eulerian and Lagrangian perspective

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Simple continuum models of granular flow provide not only fundamental insight into how and why granular materials mix but also novel examples of complex nonlinear dynamics. The same kinematic framework can be used to study mixing in fluid and granular flows, yet there are striking differences in the observed behavior. These are highlighted through a computational–experimental study of granular flow in a slowly-rotating quasi-two-dimensional polygonal container.

In the Lagrangian frame, we study trajectories of passive tracers. For small numbers of revolutions of the container, a minimal model termed "streamline jumping" captures the dynamics at the limit of a vanishingly-thin surface flowing layer. This model possesses none of the "usual" characteristics of a chaotic system, yet it leads to complex particle trajectories that resemble chaos. Connections between this physical systems and a new branch of pure mathematics—"piecewise isometries"—are discussed.

In the Eulerian frame, mixing can be characterized through the properties of the associated advection-diffusion operator. For intermediate numbers of revolutions, naturally-persistent granular mixing patterns (the "strange" eigenmodes of this operator) are observed in experiments. Unlike fluid mixing, however, strong diffusive effects due to particle collisions in the fluidized layer result in fast decay of these transient patterns in monodisperse mixtures. A modified mapping method for scalar transport, which can capture these effects numerically, is proposed. Meanwhile, segregation of bidisperse granular materials leads to permanent excitation of eigenmodes, with the segregation pattern taking the shape of the strange eigenmodes. This can be understood in terms of kinematic barriers to mixing, which are analyzed using Poincaré sections and finite-time Lyapunov exponent fields, because transport alone cannot undo the effect of segregation, once it has taken place.

BIOGRAPHY

Dr. Christov received his Ph.D. in Engineering Sciences and Applied Mathematics from Northwestern University in June of 2011, where he was a Walter P. Murphy Fellow. Subsequently, he was awarded an NSF Mathematical Sciences Postdoctoral Research Fellowship and is currently a Visiting Postdoctoral Research Fellow in Prof. Howard A. Stone's Complex Fluids Group at Princeton University. Previously, he had interned at the U.S. Naval Research Laboratory and the ExxonMobil Upstream Research Company. His research interests are primarily in the area of mathematical modeling and numerical simulation of nonlinear and complex systems, with an emphasis on transport and wave phenomena. He has been recognized with a Best Student Paper Award at both the 6th and 7th IMACS International Conferences on Nonlinear Evolution Equations and Wave Phenomena. Recently, he has been a short-term visiting researcher at the School of Mathematics at the University of Bristol and the Department of Applied Mathematics at the University of Leeds. He has been invited to speak at organized sessions at the 7th International Congress on Industrial and Applied Mathematics, the Lorentz Center in Leiden, the Department of Chemical and Biological Engineering at the University of Sheffield, and the 8th International Congress on Thermal Stresses. He has published over 20 articles in peer-reviewed scientific journals.

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