6-2009

Editorial: Advances in the Dynamics of Granular Materials

Florin Bobaru
University of Nebraska - Lincoln, fbobaru2@unl.edu

J. S. Chen
Department of Civil and Environmental Engineering, University of California at Los Angeles

Joseph A. Turner
University of Nebraska - Lincoln, jaturner@unl.edu

Published in *Mechanics of Materials* **41**:6 (June 2009), pp. 635-636; doi 10.1016/j.mechmat.2009.02.007

Submitted February 24, 2009; published online March 6, 2009.

EDITORIAL: Advances in the Dynamics of Granular Materials

Florin Bobaru,[a] J. S. Chen,[b] and Joseph A. Turner [a]

[a] Department of Engineering Mechanics, University of Nebraska–Lincoln, W317.6 Nebraska Hall, Lincoln, NE 68588-0526
[b] Department of Civil and Environmental Engineering, University of California at Los Angeles

Corresponding author — F. Bobaru, tel 402 472-8348, fax 402 472-8292, email fbobaru2@unl.edu

Granular materials exhibit a complex array of phenomena which makes the prediction of their behavior extremely difficult. Granular materials are strongly dissipative and show collective (heap formation, jamming) and size segregation phenomena, and can propagate surface waves. They display fluidization and convective motion, and under certain vibration regimes, they tend to mix when they would otherwise segregate, and segregate when they might otherwise mix. The wide range of behaviors that granular materials can display has been one of the main factors for which the development of predictive models has continued to remain an open problem.

The papers in this Special Issue on Advances in the Dynamics of Granular Materials show some recent theoretical, computational, and experimental results in various aspects of the mechanics of granular materials. A better understanding of the mechanics (and especially dynamics) of granular matter can lead to significant savings in energy and costs in various industries, such as pharmaceutical and chemical industries, food and agriculture, mining and oil extraction, construction, and transportation. The papers in this issue address fundamental and practical issues in the mechanics of granular matter.

The subject of the mechanics of granular materials is too vast for the papers in this issue to encompass fully. Nevertheless, the papers in the present issue address some critical issues on various aspects of the mechanics of granular matters that are essential to the future growth of the field.

Goddard and **Didwania** propose a continuum model for the dynamics of shallow non-cohesive granular layers driven by vertical vibration of a horizontal rigid plate. Linear stability, kinks and oscillations, and comparisons with experimental results are analyzed. The objective of this work is to properly represent the complex material behavior where phenomenological models have intrinsic limitations. **Andrade** and **Tu** develop a semi-concurrent multiscale method to extract the behavior of granular materials directly from the granular structure. The method extracts dilatancy and frictional resistance from the granular structure, and their evolution is upscaled into classical two- and three-invariant plasticity models, bypassing phenomenological hardening laws. **Guan**, **J. S. Chen, Wu, Teng, Gaidos, Hofstetter,** and **Alsaleh** propose a Semi-Lagrangian Reproducing Kernel formulation for modeling earth moving operations. Stability analyses of the Lagrangian and the semi-Lagrangian reproducing kernel formulations are presented and validated. The paper demonstrates how semi-Lagrangian reproducing kernel formulation is effective in representing continuum description of material segregation and mixing that exist in earth moving operation and other granular material applications.

A first attempt to analyze the potential use of granular materials as energy absorbing systems for crashworthiness design is performed by **Lee, Ma,** and **Kikuchi**. The analytical model developed is based on the modified effective thickness theory of tubes filled with granules, and the results are favorably compared with those from finite element simulations. Using coupled DEM–FEM models to simulate the bending of a granular layer, **Rattanadit, Bobaru, Promratana,** and **Turner** find that a reversal of the force chains structure takes place and results in a stiffening effect with increased thickness of the layer. The effective bending stiffness of the granular layers leads to Young's moduli values that are significantly lower than those obtained from wave speed measurements in granular systems, pointing to an important mechanism of deformation in granular systems with consequences for mixing and segregation processes. The DEM is used in **Zhou** and **Ooi** to investigate the pressure dip under granular piles. Both spherical and non-spherical particles are used. The results are in good agreement with experimental observations and they settle some earlier controversies on this issue.

Contact dynamics (CD), an alternative to the classical DEM models, is extensively reviewed by **Radjai** and **Richefeu.** While in DEM particles are treated as rigid bodies, the contacts between them are assumed to be viscoelastic. In the CD method the small scales are neglected and their effects are incorporated in contact laws together with a nonsmooth formulation of particle dynamics. The proposed CD method is presented as a consistent model of nonsmooth and multicontact granular dynamics. **Azéma, Radjai,** and **Saussine** employ contact dynamics simulations to investigate the influence of the particle shape (irregular polyhedral versus spherical) on the macroscopic behavior. The force anisotropy induced by the particle shapes results in enhanced shear strength compared to that of the sphere packing.

Antony and **Sultan** study the micromechanical characteristics of charged granular media under quasi-static shearing to understand the constitutive behavior of charged granular materials. The effect of charging is more pronounced in low frictional systems. The shear strength and micro-descriptors in bidispersed ellipsoid systems under large strain subjected to low to elevated confining pressures are analyzed by **Ng** using the DEM. Several micro-descriptors are shown to relate well with the mobilized shear strength at the peak state.

Experimental results are compared with DEM simulations of sheared granular systems in annular shear cells by **Ji, Hanes,** and **Shen**. Boundary conditions, particle size distribution, particle damping and sliding and rolling friction, and different contact force model are examined to determine their effects on the computational results. It was found that of the above, the rolling friction between particles had the most significant effect on the macro stress levels. **Song, W. Chen,** and **Luk** use a Split Hopkinson pressure bar technique to obtain dynamic compressive stress–strain curves of dry sand at high strain rates. The results show that the compressive response of the dry sand is highly dependent on the initial density and lateral confinement level, but not sensitive to strain rate under the loading conditions. **Martin, W. Chen, Song,** and **Akers** perform experiments to determine the effects of moisture on the high strain-rate behavior of sand. The results indicate that partially saturated sand is more compressible than dry sand with the softest behavior observed at 7% moisture content. It is presumed that pore water acts as a lubricant at the inter-particle contact areas, decreasing the friction between the particles resulting in lower localized shear stresses.

In closing, we would like to express our deepest gratitude to all paper reviewers' great contribution to this special issue. Without their highest professional input, this special issue would simply not have been possible. We would also like to extend our sincerest thanks to Professor Sia Nemat-Nasser, the Editor-in-Chief of *Mechanics of Materials,* for his encouragement and support throughout the year-long process of editing this special issue. Our sincerest thanks also go to Editorial Assistant of *Mechanics of Materials,* Ms. Margot Leong, for helping us at every step along the way and expertly coordinating the whole process.