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GRANULAR AND MULTIPHASE FLOWS

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October 4, 2012 2:30 – 4:00 p.m.
Mechanical Engineering Center – Room 224

On the Highly Nonlinear Dynamics of 1d Granular Materials and Tensegrity Systems

The talk is focused on two connected topics regarding the highly nonlinear dynamics of granular materials and tensegrity systems.

Regarding granular materials, ecent results on the wave dynamics of one-dimensional lattices of granular particles supporting energy transport through solitary waves are presented. The evolution of such particle systems toward energy equipartition, as predicted by statistical mechanics, is analyzed. Moreover, evolutionary algorithms are employed to investigate the optimal design of composite protectors composed of beads of various size, mass, and stiffness. We compute the performance of the candidate solutions under given impact loadings through a Runge-Kutta time-discretization of Hamilton's equations of motion. A general feature we observe in the optimized protectors is the transformation of incident waves into a collection of interacting reflected and transmitted solitary pulses, which in particular form an extended (long-wavelength), small-amplitude wave that travels to the wall. We also find that optimization randomizes these systems (adding to their disorder) and produces a marked thermalization. We constantly observe (in the absence of forced symmetry constraints) the appearance of soft/light beads near the wall, hard/heavy beads near the end impacted by the striker, and alternating hard and soft beads in the central section of the optimized chains. The observed "shock mitigation" behavior allows one to think of granular protectors in a new way—as tunable kinetic systems rather than purely as a means to add dissipation. Consequently, they offer the exciting possibility of creating much more effective energy transformation and shielding devices.

The second part of the talk deals with a novel application of tensegrity structures, exploring their use as networks supporting energy transport through solitary waves. We show that the elastic potential of a 'regular minimal tensegrity prism' supports solitary waves with profile dependent on the wave speed. We numerically study the shape of such a profile over a wide range of wave speeds, showing that it localizes on a single lattice spacing (i.e., on a single prism) in the limit for the wave speed tending to infinity. This feature of tensegrity structures has not yet been investigated in the literature, and could pave the way to the use of 'tensegrity lattices' (or 'crystals') as novel materials to control stress propagation and produce energy trapping; innovative tendon- and strut-controlled structures for seismic applications; as well as in novel acoustic devices, in order to create acoustic lenses capable of focusing pressure waves in very compact regions in space.

Fernando Fraternali is an Associate Professor of Structural Mechanics in the Civil Engineering Dept. of the University of Salerno, Italy. He received a M.S/B.S. in Civil Engineering from the University of Salerno, the Research Habilitation in Mechanics of Solids and Structures, and a PhD in Multiscale Mechanics from the King's College, London. He is author of a large number of well-cited peer reviewed publications, and he has participated as a PI or co-PI in various research projects funded by Italian national research organizations and U.S. research agencies. Most of his research work concerns multiscale modeling and simulation of materials and structures; multiscale fracture mechanics; design, analysis and experimentation of innovative materials, such as environmentally compatible composite materials, nanomaterials and biomaterials; nonlinear dynamics of materials and structures; structural optimization; and mechanics of masonry structures. Prof. Fraternali is a Fulbright Research Scholar, and is a Visiting Associate in Aeronautics at the California Institute of Technology. He serves on the Editorial Board for *Mechanics Research Communications*, and is a member of the International Association for Computational Mechanics (IACM), the International Society of Mesomechanics (ISM), the European Mechanics Society (EUROMECH), the European Research Center "Laboratoire Lagrange", and the Bioengineering Society (UK).

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