Granular Micromechanics: a paradigm for bridging grain interactions and micromorphic continuum descriptions

Anil Misra, Glenn L. Parker-James L. Tyson Professor of Engineering Mechanics, amisra@ku.edu
Civil, Environmental and Architectural Engineering Department, University of Kansas, Lawrence

For many problems in science and engineering, it is necessary to describe the emerging macro-scale behavior of materials formed of a very large number of grains by accounting for the micro-scale phenomena. Such materials are ubiquitous and impact diverse areas of engineering and science ranging from material development to biomaterials to geophysics. For such problems, continuum models are a preferred approach. Classical continuum theory is unable to take into account the effects of complex kinematics and distribution of elastic energy in internal deformation modes within the continuum material point. Therefore, there is a need for microstructure informed continuum models accounting properly for the deformation mechanisms identifiable at the micro-scale. Thus, mathematical description of their mechanical response must begin from the conception of grain-interactions. From this point of departure, either discrete or continuum descriptions can be elaborated. The question remains though how to analyze efficiently these materials with complex microstructures and grain-interactions [1]. Even more importantly, how can the granular structure and grain-scale mechanics be predefined to produce predictable material behavior? [2]

With the aid of examples from discrete simulations and continuum models, and novel grain-scale experimental measurements, this presentation will show why/where traditional approaches are not successful and challenge us to seek innovations. The presentation will emphasize simplicity over complexity, following energy and variational methods to deduce tractable and plausible models and explanations. Almost 3-decade-old measured kinematics (displacements and rotations) in disk assemblies [3] and new experiments with controlled grain interactions [4], will be utilized as basis to motivate the granular micromechanics approach (GMA). This approach provides a paradigm that bridges the discrete models to appropriate continuum model, and obviates the need for extensive mechano-morphological parameters required for discrete models. Through GMA, micromorphic continuum model connected to the grain-scale can be deduced [1,5-6], which show on one hand the type of information lost, and on the other, the advantages gained when adopting this type of continuum model. The obtained model provides interesting predictions for granular media. These include wave dispersions and frequency band gaps [7-9], chirality and negative Poisson's ratio [4,10-12], and mesh independent damage localization [13].

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Short biography of Dr. Anil Misra, Glenn L. Parker-James L. Tyson Professor of Engineering Mechanics

Anil Misra, Ph.D., P.E., Fellow AAAS, ASCE, EMI, AIMBE, received his bachelor's degree in civil engineering from the Indian Institute of Technology, Kanpur, India, and his M.S. and Ph.D. degrees from the University of Massachusetts at Amherst. He is currently the Glenn L. Parker-James L. Tyson Professor of Engineering Mechanics in the Civil, Environmental and Architectural Engineering Department of the University of Kansas, Lawrence. He also serves as Associate Director of the University of Kansas Institute for Bioengineering Research (KU-IBER). Dr. Misra has a broad research interest that spans topics covering both basic and applied aspects of mechanics of geomaterials, interfaces and biomaterials, including analytical, computational and experimental granular micromechanics, particle and atomistic methods, multi-scale modeling, constitutive behavior, micro-macro correlations, and multi-modal material characterization using high resolution techniques. He has co-edited four books; guest edited four journal special issues; and authored more than 300 papers in journals, edited books and conference proceedings. He has made more than 180 presentations of his research results at national and international fora. His research has been funded by a variety of sources, including the United States National Science Foundation, National Institute of Health, and private industry. He is active in various professional societies where he has been honored with election to the grade of fellow. He serves as reviewer and editorial board member of a number of journals as well as for funding agencies. He has been honored with the 2017 Eugenio Beltrami Senior Scientist Prize, various research and teaching awards at his home institutions, and Chair/Visiting Professorships at a number of international universities. (webpage: http://people.ku.edu/~amisra/).