Society of Engineering Science 51st Annual Technical Meeting

1–3 October 2014

Purdue University, West Lafayette, Indiana, USA

Thermomechanics-based granular micromechanics rate dependent coupled damage-plasticity model

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ABSTRACT

Materials with granular or pseudogranular microstructure exhibit significant effect of grain-scale mechanisms on the macroscale behavior. In these material systems, the relevant representative unit can be described as collection of grains formed by the aggregations of atoms or molecules such that the intragranular interactions are qualitatively different from intergranular interactions. In some materials, such grains are easily identifiable with distinct grain boundaries, such as in the cases of grain packings. However, there are a number of materials in which the grain identification is not straightforward although they exhibit a strongly granular texture. In either case, the evidence of granular nature of materials and the ideas of coarse graining by combining atoms and molecules into larger grains have been prevalent. The granular micromechanics paradigm offers a feasible approach for developing continuum models for these materials. The granular micromechanics approach traces its genesis to the continuum models of grain packings developed in the second-half of the last century; however, this approach has antecedents in the early development of continuum mechanics. The resultant models offer the versatility of investigating the influence of both the macro-scale parameters and the grain-scale parameters on the overall stress–strain response by incorporating the effect of nearest neighbor grain interactions through the intergranular force–displacement relationship and orientation vector. The advantages are clear because (i) the computational needs are far smaller than that of other particulate approaches, such as DEM; (ii) the models naturally exhibit macro-scale effects such as material density and inherent and loading-induced anisotropy effects; and (iii) can readily represent microscale effects of particle interactions, including rate effects. In recent years, these models have undergone further refinement and have been successfully applied to model a number of phenomena exhibited by granular materials. In the proposed presentation, we will trace the development of granular micromechanics framework and focus on some recent results obtained by derivations based upon thermomechanics, which allow for the evaluation of thermodynamic consistency of the derived models.