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Multiresolution Analysis for Material Design

Wing Kam Liu

Department of Mechanical Engineering, Northwestern University, Evanston, IL, 60208
w-liu@northwestern.edu

ABSTRACT

The relationship between material microstructure and properties is the key to optimization and design of lightweight, strong, tough materials. Material properties are inherently a function of the microscale interactions at each distinct scale of deformation in a material. Currently, we rely on empirical data to define the structure-property link in the material design chain. A model is proposed here in which a material is physically and mathematically decomposed to each individual scale of interest. Material deformation can subsequently be resolved to each of these scales. Constitutive behavior at each scale can be determined by analytically or computationally examining the micromechanics at each scale. The proposed multiresolution technique is capable of linking overall material properties to the underlying microstructure via the micromechanics at each scale of interest. The small scale deformation phenomena which have a profound impact on macroscale properties are captured. The technique is general enough to be used in any material which exhibits different constitutive behavior at each scale. It can be implemented in a general finite element framework. This is illustrated for a polycrystalline material, a granular material, an alloy containing particles at two scales. A potential use for a bio-inspired self healing composite is also discussed. The theory can then be applied computationally in a finite element framework to determine the overall material properties in terms of the constitutive behavior at each scale, without resorting to empiricism.

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