Homogenization Based Analysis and Design of Composites

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ABSTRACT

Computational homogenization is demonstrated as a potent analysis tool that can be used directly to predict the property-structure relationships of many existing classes of composites, and indirectly to design the topological macrostructure of new generations of composites so as to optimize their mechanical properties. This paper lays out the homogenization analysis problem for general classes of inelastic mechanical composites. The analysis techniques presented are logically divided into a stress- and strain-controlled methods, both of which are formulated for periodic composites in a finite element setting. A well-recognized issue with computational homogenization is that for 3-D material structures, associated computing costs escalate rapidly with mesh refinement, thus providing a potential obstacle to usage of the method. To address this important issue, the relative performance of alternative vector and parallel numerical algorithms that facilitate high speed and efficiency with computing resources are compared on sample homogenization computations of inelastic Byzantine masonry and modern graphite-epoxy. Building upon the established homogenization analysis framework, a novel method for designing the topology of a composite’s macrostructure is then formulated, implemented, and demonstrated to achieve new material designs with significantly enhanced mechanical performance properties.