Computational homogenization: advantages and challenges of decoupling

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ABSTRACT

The method of computational homogenization analyses based on numerical material testing (NMT) [1] and plate testing (NPT) [2] have indisputable superiority over FE^2-type micro-macro coupling schemes, though there are some issues to be resolved or examined. In particular, the decoupling of micro- and macroscopic analyses makes the homogenization-based two-scale analysis methods computationally law-cost and thus practical in view of industrial applications, but at the same time requires us to prepare reliable macroscopic constitutive models. To identify promising research directions for two-scale analyses, we introduce three selected topics described below to discuss the advantages and challenges of NMT and NPT.

A major advantage in the first topic is that macroscopic inelastic constitutive models for a variety of composite materials can easily be determined with reference to the material models assumed for periodic microstructures (unit cells), if the small strain assumption is valid. However, NMTs with finite deformation of resins often cause some trouble. That is, even though isotropic multiplicative finite visco-plastic models is originally developed and introduced for NMTs, the formulation of the corresponding anisotropic model for macroscopic analyses is not always possible.

The second topic arises from the method of NPT for composite plates, which enables us to evaluate the relationship between macroscopic resultant stresses and generalized strains. The originally formulated microscopic problem is featured by the in-plane periodic boundary conditions, which properly reproduces all the plate's deformation modes. If we confine ourselves to linearly elastic material behavior, even the topology optimization of microscopic plate's cross-sections is successfully conducted to maximize the performance at macro-scale. Nonetheless, we may not meet a macroscopic plate model that can accommodate the NPT results of nonlinear material behavior assumed for the in-plane unit cell.

The third subject of study is related to the method of isogeometric analyses (IGA)[3] for NMT and NPT. Since the treatment of the combination of different materials in IGA models is not trivial especially along with periodicity constraints, the first priority is to clearly specify points at issue in the numerical modeling, or equivalently mesh generation, for IG homogenization analysis (IGHA). The most important issue is how to generate patches for NURBS representation of the geometry of a rectangular parallelepiped unit cell to realize appropriate deformations in consideration of the convex-full property of IGA and the in-plane periodicity. A promising coping technique is proposed and numerically demonstrated.

REFERENCES

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