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Prediction of Effective Properties for Hyperelastic Materials with Large Deformation Behavior vis FEM-Cluster Based Analysis (FCA)

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ABSTRACT

Advanced heterogeneous materials are widely used in many fields because of their excellent properties, especially those with hyperelastic properties and significant deformation behavior. Highly efficient numerical prediction methods of nonlinear mechanical properties of heterogeneous material provide essential tools for two-scale material and structural analysis, data-driven material design, and direct application in various engineering fields. Recently, the Clustering-based Reduced Order Model (CROM) methods [1-6] have proven effective in many nonlinear homogenization problems. However, some CROM methods would need help predicting significant large deformation behavior with more than 50% true strain. This presentation introduces the FEM-Cluster based Analysis (FCA: one of the CROM methods) method and extends it to predict the effective properties of hyperelastic materials with significant large deformation. The FCA is formulated in a consistent framework of the finite element method. It makes no use of reference material and the Lippmann-Schwinger integral equation, which is different from many approaches in the field of micromechanics. With this characteristic, the basic governing equation of FCA is constructed on the current configuration of actual material based on the Hill-Mandel condition of large deformation. Moreover, the finite element implementation is derived based on the proposed stress increment and the variational principle. On this basis, the offline algorithm of FCA under large deformation is derived, including clustering the Representative Volume Element (RVE) and constructing the interaction matrix. Then the online incremental algorithm is established based on the principle of cluster minimum complementary energy with the tangent stiffness matrix. The proposed method predicts the significant deformation behavior and effective stress-strain curve of hyperelastic materials under different loading cases. Several numerical examples prove the efficiency and effectiveness of this method.

KEYWORDS

Hyperelastic materials; large deformation behavior; FEM-cluster based analysis; effective properties

Conflicts of Interest: The authors declare that they have no conflicts of interest to report regarding the present study.

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