Towards optimal design of multiscale nonlinear structures and reduced order modeling approaches

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Abstract

In recent years, there has been an increasing use of high-performance heterogeneous materials such as fibrous composites, concrete, metallic porous materials and metal alloys for their advantageous overall characteristics, which result in superior structural mechanical responses and service performance. Though from a structural point of view these materials can be considered homogeneous and conventional design approaches for homogeneous structures can still be used, the pronounced heterogeneities have a significant impact on the structural behavior. Therefore, in order to allow for reliable mechanical designs, one needs to account for material microscopic heterogeneities and constituent behaviors so as to accurately assess the structural performance. This work initially discusses the topology optimization design of nonlinear highly heterogeneous structures. Generally speaking, topology optimization design of multiscale structures can be viewed as an extension of conventional monoscale designs, except that the material constitutive law is governed by one or multiple Representative Volume Elements (RVEs) defined at the microscopic scale. Secondly, simultaneous designs of the topologies of both macroscopic structures and microscopic materials are carried out. In other words, by topology optimization we determine not only the optimal spatial material layout distribution at the macroscopic structural scale, but also the optimal local use of the cellular material at the microscopic scale. Meanwhile, several reduced-order modeling approaches have been adopted within the proposed multiscale design framework to alleviate the extremely high computing cost in multiscale modeling and design.

Keywords: Topology optimization, Multiscale modeling, Model reduction, 3D Printing

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