Computational Analysis and Design of Complex Heterogeneous Materials
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Abstract: Most high-performance materials are heterogeneous and possess complex micro/nanostructures. From the design perspective, we need to comprehend the microstructure-property relationships and tailor the material microstructure to achieve key performance characteristics, e.g., stiffness and strength. This talk elucidates a top-down approach in the computational modeling and design of multi-functional materials. To enable the accurate and efficient analysis of complex heterogeneous materials, a NURBS-based interface-enriched generalized finite element method (NIGFEM) has been developed. This approach, which incorporates Non-Uniform Rational B-Splines (NURBS) into the FE scheme, avoids the need for conformal discretization while capturing with great accuracy the geometric complexities present in the material microstructure. The NIGFEM relies on the enrichment of the approximation space to capture weak or strong discontinuities of the solution field along material interfaces. The key advantages of the method include (i) precision and convergence properties at least as good as those of the conventional FEM without the need for conforming meshes, (ii) the ability to create a direct link between micro-CT images and FE models, and (iii) its applicability to a wide range of multiphysics problems (thermal, structural, electromagnetic). The NIGFEM is also particularly attractive in gradient-based microstructural shape optimization, as it avoids the mesh distortion issues that ‘plague’ conventional FE-based shape optimization techniques. Several case studies ranging from advanced structural materials to multi-functional, biomimetic composites are presented to contrast the simulation capabilities of the NIGFEM to those of more conventional approaches. The remainder of the talk highlights ongoing and future research activities for the development and application of mathematical, computational and statistical tools for advanced materials.

Bio: Dr. Masoud Safdari received his B.Sc. in Mechanical Engineering (2004) from Isfahan University of Technology, and his M.Sc. in Mechanical Engineering (2007) from Amirkabir University of Technology, both in Iran. He then earned his Ph.D. (2012) in Engineering Science and Mechanics from Virginia Tech. He is currently a postdoctoral research associate in the Department of Aerospace Engineering at the University of Illinois. Dr. Safdari is the coauthor of twenty peer-reviewed journal articles and one book chapter. Some of his awards include an ASC PhD Scholarship Award (2012) from the American Society of Composites, and the Manual Stein Scholarship Award (2012) from Virginia Tech. His research interests include experimental, theoretical and computational solid mechanics, novel multifunctional nanocomposites and bio-inspired materials.

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