Computational multilength scale design of deformation processes: Towards an accelerated insertion of materials

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ABSTRACT

Computational methods for deformation processes have reached a very mature level accounting for microstructure evolution during processing by incorporating texture development, recrystallization, grain growth and other mechanisms. Even though significant additional modeling and experimental work is needed to fully understand the evolution of microstructure and its effect on properties in materials processing, this presentation will attempt to set forward a number of fundamental multi-length scale process design problems that can be used to obtain materials with desired microstructure-sensitive properties.

In the first part of this talk, a comprehensive review will be presented of recent advances in the development of computational algorithms for the design of multi-stage deformation processes that lead to products of desired properties. The computational design problems will be cast as optimization problems and regularized continuum sensitivity algorithms will be presented for computing the gradient of the objective function and constraints. A unified approach to both preform (shape) design and process parameter design problems will be discussed. A number of multi-stage forming process design examples will be presented to demonstrate the use of design simulators in accelerating materials insertion.

In the second part of the talk, we will present some fundamental computational problems that need our attention in order to allow a successful use of computational materials process design in an uncertain and multi-length scale environment. Existent multi-length scale forming analysis tools (e.g. simulators that account for texture evolution) cannot be easily extended to a realistic design environment because of their computational intensity. With this in mind, we will discuss the use of reduced-order models (using proper orthogonal decomposition (POD)) to model the evolution of microstructure described by an orientation distribution function using a finite element discretization of the orientation space. The feasibility of using a universal basis of POD modes to represent all possible textures will be addressed. Particular POD modes can then be selected adaptively for an efficient multi-length scale design of arbitrary deformation processes.

Finally, we will briefly discuss the potential use of spectral stochastic finite element methods, Bayesian estimation and stochastic optimization to point to process or material parameters and their confidence intervals needed to obtain a desired product at a required robustness level. With this information at hand, robust design simulators can also be used to point to the materials testing needed to obtain the material properties at their required confidence levels. This will further re-enforce the notion that materials testing should be driven by design requirements.

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