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Self-consistent Clustering Analysis for Fast Microstructure-based Modeling of Elastoplastic Strain Softening Materials

The advent of advanced processing and manufacturing techniques provides unparalleled freedom to design new material classes with complex microstructures across scales from nanometers to meters. In this lecture a new data-driven computational framework for the analysis and design of these complex material systems will be presented. A mechanistic concurrent multiscale method called self-consistent clustering analysis (SCA) is developed for general inelastic heterogeneous material systems. The efficiency of SCA is achieved via data compression algorithms which group local microstructures into clusters during the off-line training stage, thereby reducing required computational expense. Its accuracy is guaranteed by introducing a self-consistent method for solving the Lippmann-Schwinger integral equation in the on-line predicting stage. The integration of microstructure reconstruction and subsequent high-fidelity multiscale predictions of the materials behavior leads to the generation of vast amounts of reliable data. This structure-property feedback loop enables the design of new material systems with new capabilities. In mathematical physics, the "structure" and "property" can be interpreted as the nonlocal interaction of the microstructure clusters and the virtual work at the corresponding material point, respectively. Based on the computational design of experiments, data mining techniques offer the ability to discover the influence of the microstructure on the macroscopic materials behavior. The proposed framework will be illustrated for advanced composites and the integrated design of various advanced material systems.

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