Physics Embedded Machine Learning Methods in Hierarchical Constitutive And Damage Modeling of Metals and Composites

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This talk will discuss the implementation of Machine Learning algorithms in a "parametric homogenization framework" for hierarchical multiscale modeling of deformation and damage in a wide variety of materials. Parametrically homogenized constitutive models are thermodynamically consistent, macroscopic constitutive models that bridge spatial scales through the explicit representation of microstructural descriptors in equations that constitute these models. Coefficients in PHCM equations are explicit functions of Representative Aggregated Microstructural Parameters or (RAMPs), representing statistical distributions of morphological and crystallographic descriptors of the microstructure. Machine learning algorithms, including symbolic regression and ANN, are used to create these functional forms within the window of constitutive coefficients in the equations. Major advantages of the framework are: i. Explicit representation of microstructural descriptors, specifically RAMPs, in macroscopic constitutive relations is an attribute with important implications in structure-material design. ii. Very high efficiency with good accuracy of multiscale solutions, is a requirement for most data driven design algorithms. The talk will be conducted in three segments, viz. (i) Parametrically homogenized constitutive models or PHCMs for deformation and fatigue in metals and alloys, (ii) Parametrically homogenized continuum damage mechanics or PHCDM models for deformation and damage in composites and (iii) data-driven methods for fatigue modeling. We will conclude with a general assessment of the high efficiency and accuracy of these methods.