Machine Learning Enabled Parametrically Upscaled Constitutive Models (PUCM): Data Driven Multiscale Modeling Approach for Metals and Composites

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ABSTRACT

This talk will give an overview of the development of the P*arametrically Upscaled Constitutive Model (PUCM)* for Ti alloys like Ti-6AL-4V, *Parametrically Upscaled Crystal Plasticity Model (PUCPM)* for single crystals in Ni-based superalloys and *Parametrically Upscaled Continuum Damage Mechanics Model (PUCDM)* for composites. These thermodynamically consistent constitutive models bridge multiple spatial scales through the explicit representation of representative aggregated microstructural parameters (RAMPs). They enable computationally efficient simulations with significant speedup over detailed lower-scale models. A host of computational tools and machine learning (ML) algorithms are developed to create an automated pipeline for parametric upscaling. The novel algorithms used include GA with support vector regression (SVR), Sobol analysis-based global sensitivity analysis, ANN for emulating the CPFE models, nonlinear optimization scheme using k-means acceleration and genetic programming symbolic regression (GPSR) for functional representation. The computational tool chain outputs the highly efficient PUCM/PUCPM/PUCDMs, which are invaluable tools for multiscale analysis of deformation and failure with implications in location-specific design.