UNCERTAINTY INTEGRATION ACROSS MULTIPLE LEVELS FOR STRUCTURE-MATERIAL PERFORMANCE ASSESSMENT

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Abstract

Model-based simulation is attractive for the performance and reliability analysis of structural and material systems under extreme conditions, since full-scale testing is often unaffordable. However, model-based simulation involves many approximations and assumptions, and thus confidence in the simulation result is an important consideration in risk-informed decision-making. Sources of uncertainty are both aleatory and epistemic, stemming from natural variability, information uncertainty, and modeling approximations at multiple levels. Information uncertainty arises from sparse and imprecise data, measurement and data processing errors, and qualitative information. Model uncertainty arises due to unknown model parameters, model form assumptions, and solution approximation errors. The presentation will discuss a Bayesian framework for the aggregation of uncertainty from multiple sources towards the reliability assessment of multi-physics, multi-scale systems, linking manufacturing process to material microstructure and properties to structural performance. Multiple activities such as calibration, verification and validation are conducted as part of the model development at multiple levels, and the results of these activities need to be systematically integrated within the overall uncertainty quantification and performance prediction. In a multi-scale modeling environment, the information available is heterogeneous, from multiple sources (models, tests, experts) and in multiple formats. A systematic integration methodology of heterogeneous information using Bayesian networks will be presented. The integration of structural health monitoring information within this uncertainty quantification framework for diagnosis and prognosis of the structure and material state will be addressed. For systems with a large number of variables, scalability of the above computational methodologies is an important concern, and new strategies for computational efficiency within uncertainty aggregation will be outlined. Different analyses and tests could be performed at different levels of fidelity, offering trade-offs between accuracy and cost; thus resource allocation strategies for different uncertainty quantification activities will be outlined, and their effect on prediction confidence under extreme conditions will be studied.