Nonintrusive Stochastic Multiscale Design System for Heterogeneous Materials

by

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ABSTRACT

Research on heterogeneous materials has attracted significant attentions due to their potential use in high performance application. The emphasis of this thesis is on a flexible design framework that is compatible with most commercial numerical packages. Due to inevitable randomness at the scale of heterogeneity resulting from manufacture process, the present framework aims at quantifying uncertainties in Quantities of Interest (QoI) at the coarse scale structure, such as critical stress and overall modulus. There are two main barriers for such a design framework to be applicable to practical design. One is the barrier associated with tremendous physical space involved with material scale which is much smaller than the component scale. The other is the barrier emanating from high dimensional probability space.

The first barrier has been addressed by reduced order homogenization. A canonical framework has been devised to provide a transparent interface linking single scale material building blocks. Users can add their own material models for fine scale phase or interface by providing single scale stress update and stress consistent tangent operator. Damage, fatigue, plasticity and viscoplasticity laws have been verified and validated with several industrial applications. This canonical framework enabled the integration of a deterministic multiscale design system with ABAQUS, LS-DYNA and FEAP.

The second barrier has been addressed by stochastic collocation methods in combination with Karhunen-Loeve expansion. In the present study, randomness has been limited to the parameters in fine scale material constitutive laws. Both low dimensional probability space (random variables) and high dimensional probability space (random fields) have been studied with individual design schemes. The collocation methods have been verified with sampling method based on Monte Carlo method (Latin hypercube sampling).