STOCHASTIC ELASTIC–PLASTIC MATERIAL MODELING

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The deterministic modeling and simulations of elastic-plastic materials has been studied extensively in the last century. Various models and simulations related to collapse analysis, localization of deformation, phase change, coupled (multi–physics) behavior have been performed successfully. However, one crucial area – point-wise and spatial variability of and uncertainty in material properties – of material modeling has received very little attention. Most of the small number of studies on effects of material uncertainty have used repetitive deterministic models through Monte Carlo type simulations. While this approach might appear sound, it cannot be both computationally efficient and statistically consistent (have statistically appropriate number of data points).

In this presentation we develop analytical methodology to account for uncertainty in elastic and inelastic (elastic–plastic) material behavior. At the constitutive level simulation (which takes into account point-wise randomness of material properties), Euler–Lagrange form of Fokker-Planck-Kolmogorov (FPK) equation, which is second-order exact, is applied to the description of the evolution of probability density function of response (strains or stresses depending upon whether load-controlled or displacement-controlled) of any general form of elastic and elastic–plastic constitutive rate equation with random material properties. The advantage of the FPK equation based approach developed here is that it doesn't suffer from the ”closure problem” associated with regular perturbation approach nor does it require repetitive use of computationally expensive deterministic elastic–plastic simulations as associated with Monte Carlo technique. Furthermore, the FPK approach transforms the nonlinear stochastic constitutive ordinary differential equation into linear deterministic partial differential equation. Even though the FPK equation is not amenable to analytical solution, the deterministic linearity greatly simplifies the numerical solution process. In addition to constitutive level developments, spatial variability of material properties, is modeled and simulated using Karhunen-Loeve expansions of input random fields in eigen-modes of their covariance function and polynomial chaos expansion with Galerkin method to represent the solution random field.

Number of examples will be presented, illustrating methodology and main results, some of which are quite surprising and can be seen, at first glance as counterintuitive.

References

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