Isogeometric method of stochastic mechanical analysis of structures

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Abstract

In practical engineering systems, there exists random property for physical and geometric parameters of structures as well as external load, and thus the structural responses have randomness. Therefore, the mechanical analysis of engineering structures considering the random factors, and the study on quantification of random uncertainty and its propagation law present the important theoretical significance and application value. Isogeometric analysis (IGA) is an emerging method for exact geometric modeling and efficient structural analysis and design. IGA adopts usually the NURBS (non-uniform rational B spline) basis function to describe geometric model exactly, and calculate the displacement and stress field of structures, which enables to integrate the CAD (computer aided design), CAE(computer aided engineering), and design optimization.

Based on isogeometric analysis and stochastic perturbation technique, this paper proposes the stochastic IGA method for mechanical analysis of two-dimensional cantilever beam and Mindlin plate with random elastic modulus. Firstly, by expressing random field with Karhunen-Loeve expansion, stochastic IGA formulas of the plane stress beam and the bending of Mindlin plate are derived. Then, the first two moments (mean and variance) of structural responses are formulated with stochastic perturbation method in the framework of IGA. Finally, numerical results of planar cantilever beam via the stochastic IGA method are verified by the Monte Carlo simulation. The effect of truncation terms in Karhunen-Loeve expansion and meshing density on the convergence of calculated results is scrutinized. Moreover, for the square Mindlin plate, the relationship between coefficient of variation of displacement response and correlation length of random field and the influence of different meshes on stochastic responses are examined. It is indicated that stochastic IGA based on perturbation theory can achieve accurately and efficiently the random responses of structures with small coefficient of variation. The random physical parameters and boundary conditions impose considerable influence on the propagation of random uncertainty of structures.

Keywords: stochastic structural analysis; perturbation method; stochastic isogeometric analysis; random field; response moments