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Response variability of cylindrical shells with stochastic non-Gaussian material and geometric properties

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ABSTRACT

In this paper, the effect of combined uncertain material (Young's modulus, Poisson's ratio) and geometric (thickness) properties on the response variability of cylindrical shells is investigated taking into account various non-Gaussian assumptions for the uncertain parameters. These parameters are described by two-dimensional univariate homogeneous non-Gaussian stochastic fields using the spectral representation method in conjunction with translation field theory. The response variability is computed by means of direct Monte Carlo simulation (MCS). It is shown that the marginal probability distribution and the correlation scale of the stochastic fields used for the description of the material and thickness variability affect significantly the shell response statistics.

1. Introduction

A powerful tool in computational stochastic mechanics is the stochastic finite element method (SFEM). SFEM is an extension of the classical deterministic FE approach to the stochastic framework i.e. to the solution of stochastic problems whose (material and geometric) properties are random with the FE method. The considerable attention that SFEM received over the last two decades can be mainly attributed to the understanding of the significant influence of the inherent uncertainties on systems' behavior and to the dramatic increase of computational power in recent years, permitting the efficient treatment of complex realistic problems with uncertainties [1,2].

A characteristic example of structures with a complex stochastic response is that of shell structures. The analysis and design of shells are challenging since their behavior can be unpredictable with regard to geometry or support conditions. In particular, the extreme sensitivity of thin shells to imperfections in material, geometry and boundary conditions requires a realistic description of all uncertainties involved in the problem. This task is realizable only in the framework of a robust SFEM formulation that can accurately and efficiently handle material and geometric uncertainties. The need for a robust, accurate and computationally efficient shell element becomes even greater for the computationally expensive SFE analysis of large realistic shell structures.

The TRIC (TRIangular Composite) shear-deformable facet shell element is a reliable and cost-effective triangular element suitable for the linear and nonlinear analysis of thin and moderately thick isotropic as well as composite plate and shell structures [3]. Its formulation is based on the natural mode finite element method, which has a number of computational advantages compared to the conventional isoparametric finite element formulations. The treatment of the element kinematics (inclusion of the transverse shear deformations in its formulation based on a first order shear-deformable beam theory) eliminates locking phenomena in a physical manner. The rigorous theoretical basis of the element has been confirmed in several publications, while numerical examples have verified its accuracy and computational efficiency in various structural applications [3–5]. An important feature of the TRIC element in the context of stochastic analysis is the fact that there is no need to perform numerical integration for the computation of its deterministic stiffness matrix, which is carried out in closed form. This special feature of the TRIC element provides an ideal basis for the formulation of a computationally efficient stochastic stiffness matrix and for the use of the element in large-scale stochastic computations.

In most SFEM applications, a straightforward randomization of only one material property is performed by assuming that this property is described by a stochastic field, e.g. [6–10]. For example, the Young's modulus is often assumed to vary randomly over space, while the Poisson's ratio is considered as a deterministic

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