力学学报 2007 39 (6(中文)): 835-842 ISSN: 0567-7718 CN: 11-2063/O3

简报

随机杆系结构几何非线性分析的递推求解方法

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收稿日期 2007-4-3 修回日期 2007-4-28 网络版发布日期 2007-11-22 接受日期

摘要 建立了随机静力作用下考虑几何非线性的随机杆系结构的随机非线性平衡方程．将和位移耦合的随机割线弹性模量以及随机响应量表示为非正交多项式展开式，运用传统的摄动方法获得了关于非正交多项式展开式的待定系数的确定性的递推方程．在求解了待定系数后，利用非正交多项式展开式和正交多项式展开式的关系矩阵，可以很方便地得到未知响应量的二阶统计矩．两杆结构和平面桁架拱的算例结果表明，当随机量涨落较大时，递推随机有限元方法比基于二阶泰勒展开的摄动随机有限元方法更逼近蒙特卡洛模拟结果，显示了该方法对几何非线性随机问题求解的有效性.

关键词 随机杆系结构 几何非线性 递推随机有限元方法 非正交多项式展开式 二阶泰勒展开

分类号 O342，TU32

Geometrical nonlinear analysis of truss structures with random parameters utilizing recursive stochastic finite element method

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Abstract

Geometrical nonlinear analysis of truss structures with random parameters is carried out using a new stochastic finite element method that is called as recursive stochastic finite element method in this paper. Combining nonorthogonal polynomial expansion and perturbation technique, RSFEM has been successfully used to solve static linear elastic problems, eigenvalue problems and elastic buckling problems. Although such method is similar in form to traditional the second order perturbation stochastic finite element method, it can deal with mechanical problems involving random variables of relatively large fluctuation levels. Different from spectral stochastic finite element method utilized widely that transforms the random different equation into a large deterministic equation through projecting the unkown random variables into a set of orthogonal polynomial bases, the new method is more suitable for solving large dimensional random mechanical problem because of recursive solution method. The structural response can be explicitly expressed by using some mathematical operators defined to transform the random different equation into a series of same dimensional deterministic equations. And more important point is that the above advantages of this presented method make it more helpful for solving static nonlinear problem than SSFEM. In the present paper, the stochastic equilibrium equation of geometrical nonlinear analysis of random truss structures under static load is firstly set up. Apart from that the random loads and the random area parameters are expanded using the first order Taylor series, both of the modulus and structural responses are expressed using nonorthogonal polynomial expansions. Then a set of deterministic recursive equations is obtained utilizing perturbation method. Transposition technique is given for solving the equations containing unknown coefficients according to operation rule of matrix and characteristics of truss structures. After the unknown coefficients are gotten, the second statistic moment can be easily obtained according to relationship matrix between orthogonal and nonorthogonal polynomial expansions. In examples, the geometrical nonlinear analysis of a two bar structure and a plane truss arch are investigated. The numerical results show that compared with traditional perturbation stochastic FEM based on the second Taylor series, the results obtained using the new method are more close to that of Monte-Carlo simulation when fluctuation of random variables becomes large. The interesting thing is that in the static geometrical nonlinear problem, when the second order perturbation stochastic finite element method is utilized, the divergence trend of the structural response also appears along with the increase of standard deviation of random cross sectional areas. However, this phenomenon disappears when the fourth order RSFEM is used to solve this problem. In the end, some significant conclusions are obtained.

Key words truss structures with random parameters geometrical nonlinear recursive stochastic finite element method perturbation stochastic finite element method the second Taylor series

DOI:

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