张志刚,齐朝晖,吴志刚,方慧青.考虑变形耦合的几何非线性空间梁单元[J].计算力学学报,2014,31(5):603~608,621

考虑变形耦合的几何非线性空间梁单元

A geometrical nonlinear space beam element with considering deformation coupling

投稿时间：2013-06-01 修订日期：2013-11-18

DOI： 10.7511/jslx201405010

中文关键词: 空间梁单元 几何非线性 大转动 节点力

英文关键词: spatial beam elements geometrically nonlinearity finite rotations nodal forces

基金项目: 国家自然科学基金（11372057）资助项目.

作者	单位	E-mail
张志刚	大连理工大学 工业装备结构分析国家重点实验室, 大连 116023	
齐朝晖	大连理工大学 工业装备结构分析国家重点实验室, 大连 116023	zhaohuiq@dlut.edu.cn
吴志刚	大连理工大学 工业装备结构分析国家重点实验室, 大连 116023 大连理工大学 航空航天学院, 大连 116023	
方慧青	大连理工大学 工业装备结构分析国家重点实验室, 大连 116023	

中文摘要:

以“精确几何模型梁单元”为代表的很多几何非线性梁单元，在构造过程中分别对描述截面转动的转角和描述截面形心位置的位移进行了独立插值，由此引起了诸如运动学描述冗余和剪切闭锁等困难。其根本原因在于单元形函数没能体现细长梁中的变形耦合关系。本文对这类传统单元进行了改造，通过深入研究单元变形之间的内在联系，提出了一种变形场完全满足Bernoulli梁变形耦合关系的新单元，避免了构造过程中对转动矢量的插值，并通过数值算例检验了单元的有效性。

英文摘要:

In the construction process of beam elements that are capable of tackling geometrical nonlinear problems,such as "the geometrically exact beam elements",the angles describing the rotation of beam sections and the displacements of centroids are interpolated independently.In such elements,the element shape functions cannot represent the coupling effects among the different kinds of deformations when a beam can be viewed as slender,resulting in some difficulties very hard to deal with,such as the redundancy in kinematic description and shear locking.In this paper,traditional beam elements are modified through the detailed study on the interrelations among different kinds of deformation of a beam.Based on the obtained results,we propose a new kind of beam element whose pattern of deformations are coincide with the pattern given by the Bernoulli beams theory,moreover,the interpolation of rotation vectors is not necessary.Three numerical examples are given to validate the proposed element.

参考文献(共12条):

[1] 吕和祥,朱菊芬.大转动梁的几何非线性分析讨论[J].计算结构力学及其应用.1995,12(4):485-490.(LV He-xiang,ZHU Ju-fen.Discussion of analyzing of geometric nonlinear beams with large rotations[J].Computational Structural Mechanics and Applications,1995,12(4):485-490.(in Chinese))

[2] Bathe K J,Bolourchi S.Large displacement analysis of three-dimensional beam structures[J].International Journal for Numerical Methods in Engineering,1979,14(7):961-986.

[3] Crisfield M A.A consistent co-rotational formulation for non-linear,three dimensional beam elements[J].Computer Methods in Applied Mechanics and Engineering,1990,81(2):131-150.

[4] 罗晓明,齐朝晖,许永生,等.含有整体刚体位移杆件系统的几何非线性分析[J].工程力学,2011,28(2):62-68.(LUO Xiao-ming,QI Zhao-hui,XU Yong-sheng,et al.Geometric nonlinear analysis of truss systems with rigid body motions[J].Engineering Mechanics,2011,28(2):62-68.(in Chinese))

[5] 蔡松柏,沈蒲生.大转动平面梁有限元分析的共旋坐标法[J].工程力学,2006,23(6):69-72.(CAI Song-bai,SHEN Pu-sheng.Co-rotational procedure for finite element analysis of plane be-am under large rotational displacement[J].Engineering Mechanics,2006,6(23):69-72.(in Chinese))

[6] Reissner E.On one-dimensional finite strain beam theory:the plane problem[J].J Appl Math Phys(ZAMP),1972,23(5):795-804.

[7] Simo J C.A finite strain beam formulation(Part I)the three dimensional dynamic problem[J].Computer Methods in Applied Mechanics and Engineering,1985,49(1):55-70.

[8] Simo J C,Vu-Quoc L.A three dimensional finite srain rod model(Part II)computational aspects[J].Computer Methods in Applied Mechanics and Enginee-ring,1986,58(1):79-116.

[9] Argyris J.An excursion into large rotations[J].Computer Methods in Applied Mechanics and Enginee-ring,1982,32(1):85-155.

[10] Cardona A,Geradin M.A beam finite element non-linear theory with finite rotations[J].International Journal for Numerical Methods in Engineering,1988,26(11):2403-2438.

[11] Ibrahimbegovic A,Frey F,Kozar I.Computational aspects of vector-like parameterization of three-dimensional finite rotations[J].International Journal for Numerical Methods in Engineering,1995,38(21):3653-3673.

[12] Mattiasson K.Numerical results from large deflection beam and frame problems analysed by means of elliptic integrals[J].International Journal for Numerical Methods in Engineering,1981,17(1):145-153.

相似文献(共20条):

[1] 段海娟,周益云,苏国韶.拱结构空间几何非线性分析的曲梁单元[J].四川建筑科学研究,2002,28(2):10-11,14.

[2] 李爽,翟长海,刘洪波,谢礼立.直接基于单元平衡的梁非线性分析方法[J].计算力学学报,2011,28(5):711-716.

[3] 陆念力,张宏生.计及纵横变形效应的几何非线性三次样条梁单元[J].吉林大学学报(工学版),2010,40(3).

[4] 陆念力,张宏生.一种高精度几何非线性递推凝聚梁单元[J].中国工程机械学报,2008,6(1):1-5.

[5] 陈滔,黄宗明.基于有限单元柔度法的材料与几何双重非线性空间梁柱单元[J].计算力学学报,2006,23(5):524-529.

[6] 朱敏,杨咏漪,任杰.空间梁单元几何非线性的随转参考点法[J].路基工程,2009(6):11-12.

[7] 吴斌.梁单元非线性几何方程的精确表达式[J].重庆交通大学学报(自然科学版),2000,19(1):102-103.

[8] 陈滔,黄宗明.基于有限单元柔度法和刚度法的几何非线性空间梁柱单元比较研究[J].工程力学,2005,22(3):31-38.

[9] 王恒华 沈祖炎.平面梁杆结构几何非线性分析的一种简便方法[J].计算力学学报,1997,14(1):119-123.

[10] 王睿,周洲,祝小平,肖伟.几何非线性机翼本征梁元素模型的高效化改进[J].航空学报,2013,34(6):1309-1318.

[11] 聂国隽,钱若军.薄壁梁元几何非线性分析模型的研究[J].空间结构,2002,8(3):35-40,34.

[12] 张剑,周储伟,叶见曙.几何非线性高性能复合材料筋混凝土梁Heterosis组合壳单元[J].复合材料学报,2010,27(2):66-71.

[13] 李国强,刘玉姝.一种考虑初始缺陷影响的非线性梁单元[J].计算力学学报,2005,22(1):69-72.

[14] 李国强,王震.一种考虑温度影响的高效几何非线性梁柱单元[J].同济大学学报(自然科学版),2016,44(6):0815-0821.

[15] 刘光栋 王解君.空间梁单元的几何非线性刚度矩阵的分解形式[J].湖南大学学报(自然科学版),1992,19(1):60-71.

[16] Xiaofeng Wang Qingshan Yang.GEOMETRICALLY NONLINEAR FINITE ELEMENT MODEL OF SPATIAL THIN-WALLED BEAMS WITH GENERAL OPEN CROSS SECTION[J].Acta Mechanica Solida Sinica,2009,22(1):64-72.

[17] 黄宝宗,姜泽亚.一个几何非线性空间变形曲梁元[J].东北大学学报(自然科学版),1987(3).

[18] 邓继华,邵旭东.带铰平面梁元几何非线性有限元分析[J].长安大学学报(自然科学版),2012,32(3):68-72.

[19] 肖建春,马克俭,董石麟,程涛.几何非线性过渡梁元[J].钢结构,2000,15(3):31-33.

[20] 徐圣,刘锦阳,余征跃.几何非线性空间梁的动力学建模与实验研究[J].振动与冲击,2014,33(21):108-113.