Ghadiri, Majid; **Safi, Mohsen**

Nonlinear vibration analysis of functionally graded nanobeam using homotopy perturbation method. (English) Zbl 07407119

Adv. Appl. Math. Mech. 9, No. 1, 144-156 (2017)

Summary: In this paper, He's homotopy perturbation method is utilized to obtain the analytical solution for the nonlinear natural frequency of functionally graded nanobeam. The functionally graded nanobeam is modeled using the Eringen's nonlocal elasticity theory based on Euler-Bernoulli beam theory with von Karman nonlinearity relation. The boundary conditions of problem are considered with both sides simply supported and simply supported-clamped. The Galerkin's method is utilized to decrease the nonlinear partial differential equation to a nonlinear second-order ordinary differential equation. Based on numerical results, homotopy perturbation method convergence is illustrated. According to obtained results, it is seen that the second term of the homotopy perturbation method gives extremely precise solution.

MSC:

74G10 Analytic approximation of solutions (perturbation methods, asymptotic methods, series, etc.) of equilibrium problems in solid mechanics
74H45 Vibrations in dynamical problems in solid mechanics
74E30 Composite and mixture properties
74K10 Rods (beams, columns, shafts, arches, rings, etc.)
74B20 Nonlinear elasticity

Keywords:

homotopy perturbation method; Lindstedt-Poincaré method; analytical solution; nonlocal nonlinear free vibration; functionally graded nanobeam

Full Text: DOI

References:

[1] R. ANSARI AND S. SAHMANI, Bending behavior and buckling of nanobeams including surface stress effects corresponding to different beam theories, Int. J. Eng. Sci., 49(11) (2011), pp. 1244-1255.

[2] A. C. ERINGEN, On differential equations of nonlocal elasticity and solutions of screw dislocation and surface waves, J. Appl. Phys., 54(9) (1983), pp. 4703-4710.

[3] A. H. NAYFEH AND D. T. MOOK, Nonlinear Oscillations, John Willey and Sons, New York, 1979.

[4] C. NASH AND S. SEN, Topology and Geometry for Physicists, Academic Press, London, 1983. · Zbl 0529.53001

[5] J. H. HE, A coupling method of a homotopy technique and a perturbation technique for non-linear problems, Int. J. Non-Linear Mech., 35(1) (2000), pp. 37-43. · Zbl 1068.74618

[6] J. H. HE, A new approach to nonlinear partial differential equations, Commun. Nonlinear Sci. Numer. Simulation, 2(4) (1997), pp. 230-235.

[7] S. J. LIAO, An approximate solution technique not depending on small parameters: a special exam-ple, Int. J. Non-Linear Mech., 30(3) (1995), pp. 371-380. · Zbl 0837.76073

[8] J. H. HE, Homotopy perturbation technique, Comput. Meth. Appl. Mech. Eng., 178 (1999), 257262. · Zbl 0956.70017

[9] M. A. FODA, Influence of shear deformation and rotary inertia on nonlinear free vibration of a beam with pinned ends, Comput. Structures, 71(6) (1999), pp. 663-670.

[10] A. RAMEZANI, A. ASGHAR, A. ARIA AND A. JAVAD, Effects of rotary inertia and shear de-formation on nonlinear free vibration of microbeams, J. Vibration Acoustics, 128(5) (2006), pp. 611-615.

[11] R. NAZEMNEZHAD AND H. SHAHROKHHOSSEINI, Nonlocal nonlinear free vibration of func-tionally graded nanobeams, Composite Structures, 110 (2014), pp. 192-199.

[12] D. A. EVENSEN, Nonlinear vibrations of beams with various boundary conditions, AIAA J., 6(2) (1968), pp. 370-372. · Zbl 0157.56302

[13] T. PIRBODAGHI, M. T. AHMADIAN AND M. FESANGHARY, On the homotopy analysis method for non-linear vibration of beams, Mech. Res. Commun., 36(2) (2009), pp. 143-148. · Zbl 1258.74110

[14] M. AKBARZADE AND D. D. GANJI, Coupled method of homotopy perturbation method and varia-tional approach for

solution to nonlinear cubic-quintic Duffing oscillator, Adv. Theor. Appl. Mech., 3(7) (2010), pp. 329-337.

[15] M. BAYAT, P. IMAN AND B. MAHDI, Analytical study on the vibration frequencies of tapered beams, Latin American J. Solids Structures, 8(2) (2011), pp. 149-162.

[16] M. T. AHMADIAN, M. MOJAHEDI AND H. MOEENFARD, Free vibration analysis of a nonlinear beam using homotopy and modified lindstedt-poincare methods, J. Solid Mech., 1(1) (2009), pp. 29-36.

[17] H. MOEENFARD, M. MAHDI AND M. T. AHMADIAN, A homotopy perturbation analysis of nonlinear free vibration of Timoshenko microbeams, J. Mech. Sci. Tech., 25(3) (2011), pp. 557-565.

[18] M. POORJAMSHIDIAN, J. SHEIKHI, S. MAHJOUB-MOGHADAS AND M. NAKHAIE, Nonlinear vibration analysis of the beam carrying a moving mass using modified homotopy, J. Solid Mech., 6(4) (2014), pp. 389-396.

[19] A. A. YAZDI, Applicability of homotopy perturbation method to study the nonlinear vibration of doubly curved cross-ply shells, Composite Structures, 96 (2013), pp. 526-531.

[20] H. M. SEDIGHI, M. HAMID, KOUROSH H. SHIRAZI AND J. ZARE, An analytic solution of transversal oscillation of quintic non-linear beam with homotopy analysis method, Int. J. Non-Linear Mech., 47(7) (2012), pp. 777-784.

[21] H. M. SEDIGHI AND F. DANESHMAND, Nonlinear transversely vibrating beams by the homotopy perturbation method with an auxiliary term, J. Appl. Comput. Mech., 1(1) (2014), pp. 1-9.

[22] J. H. HE, Modified Lindstedt-Poincare methods for some strongly non-linear oscillations: Part I: expansion of a constant, Int. J. Non-Linear Mech., 37(2) (2002), pp. 309-314. · Zbl 1116.34320

[23] J. H. HE, Modified Lindstedt-Poincare methods for some strongly non-linear oscillations: Part II: a new transformation, Int. J. Non-Linear Mech., 37(2) (2002), pp. 315-320. · Zbl 1116.34321

[24] J. N. REDDY, Nonlocal theories for bending, buckling and vibration of beams, Int. J. Eng. Sci., 45(2) (2007), pp. 288-307. · Zbl 1213.74194

[25] W. LESTARI AND S. HANAGUD, Nonlinear vibration of buckled beams: some exact solutions, Int. J. Solids Structures, 38(26) (2001), pp. 4741-4757. · Zbl 0989.74028

[26] G. SINGH, A. K. SHARMA AND G. V. RAO, Large-amplitude free vibrations of beamsa discussion on various formulations and assumptions, J. Sound Vibration, 142(1) (1990), pp. 77-85.

[27] R. ZHU, P. ERNIAN, PETER W. CHUNG, X. L. CAI, KIM M. LIEW AND ALPER BULDUM, Atomistic calculation of elastic moduli in strained silicon, Semiconductor Sci. Tech., 21(7) (2006), pp. 906-911.

[28] S. OGATA, J. LI AND S. YIP, Ideal pure shear strength of aluminum and copper, Science, 298(5594) (2002), pp. 807-811.