Chaos type identification in the contact interaction of closed cylindrical nanoshells embedded one into another with a gap between them

Papkova I.V., Yakovleva T.V., Krysko A.V., Krysko V.A.
Department of Mathematics and Modeling, Yuri Gagarin State Technical University of Saratov, Saratov, Russia

Abstract. A contact interaction theory of closed cylindrical nanoshells embedded one into another is constructed in the work. Between the shells there is a small gap. Cylindrical nanoshells are elastic, homogeneous, isotropic, subject to the kinematic hypothesis of the first approximation (Kirchhoff-Love), geometric nonlinearity is taken into account according to the T. von Karman theory, and contact interaction is taken as Winkler model corresponding to the Kantor B.Ya. theory. Size-dependent effects are taken into account according to the modified moment theory of elasticity. This work is the first to analyze the chaotic oscillations type of closed cylindrical nanoshells during their contact interaction. The chaos type analysis is carried out according to the Gulik criterion and based on the calculation of the Lyapunov exponents spectrum signs by the Sano-Sawada method. To confirm the reliability of the results obtained, the senior Lyapunov indices are calculated by several methods: Wolf, Kantz, Rosenstein and Sano-Sawada.

Introduction

Closed cylindrical shells are widely used in various engineering structures, instrumentation, medicine, aircraft and rocket construction. In this regard, works on theoretical studies of such structures in the world literature are presented very widely [1-3]. Cylindrical nanoshells are the building blocks of nanoelectromechanical structures (NEMS). Contact interaction of individual elements affects the operating mode of the entire device [4]. This work aim is to construct a contact interaction theory of closed cylindrical nanoshells nested one into another with a small gap between them and under the external loads action. This work is the first to analyze the chaotic oscillations type of these nanoshells as a result of their contact.

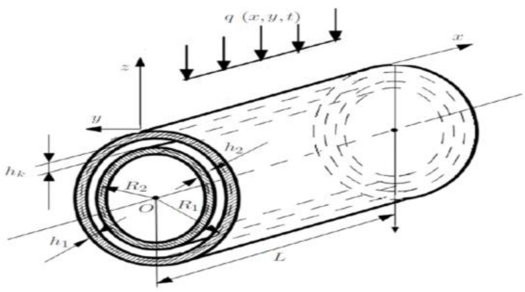

Figure 1: Scheme of closed cylindrical nanoshells.

Results and discussion

The nonlinear partial differential equations system reduces to the Cauchy problem by the Faedo-Galerkin method in higher approximations in spatial coordinates. The Cauchy problem is solved by several methods: the Runge-Kutta type methods from second to eighth accuracy orders and the Newmark method to confirm reliable results. The chaos type analysis of a closed cylindrical nanoshell under the external transverse distributed strip load action is carried out. It was revealed that the oscillations type significantly depends on the amplitude and frequency of the load, size-dependent and geometric parameters, as well as on the series members number in the Faedo-Galerkin method. The cylindrical shell can perform harmonic or chaotic oscillations, while, depending on the number of positive Lyapunov spectrum exponents, two types of chaos are observed: chaos and hyperchaos. A dynamic characteristics analysis of a cylindrical nanoshell nonlinear oscillations showed that the Ruelle-Takkens-Newhouse oscillations transition scenario from harmonic to chaotic is typical for all considered cases.

This work is supported by the Russian Science Foundation grant No. 19-19-00215.

References

[1] M.P.M.Amabili (2003) Review of studies on geometrically nonlinear vibrations and dynamics of circular cylindrical shells and panels, with and without fluid-structure interaction, *Appl. Mech. Rev.* **56** 349–381.

[2] F.Alijani, M.Amabili (2014) Non-linear vibrations of shells: a literature review from 2003 to 2013, *Int. J. Non-Linear Mech.* **58 (0)** 233–257.

[3] O.A. Saltykova, O.A. Afonin, T.V.Yakovleva, A.V. Krysko (2018) The chaotic dynamics of closed cylindrical nanoshells under local loading, *Nonlinear World*, **Vol. 16, No. 5,** p. 3-15.

[4] Yakovleva T., Krysko-jr. V., Krysko V. (2019): Nonlinear dynamics of the contact interaction of a three-layer plate-beam nanostructure in a white noise field. *Journal of Physics: Conference Series*. **1210** 012160.