Nonlinear dynamics of NEMS / MEMS elements in the form of flexible beams taking into account the temperature field, radiation exposure and elastoplastic deformations

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Abstract. A nonlinear vibrations theory of flexible beam elements NEMS / MEMS is constructed in this work. Nanobeams are considered as the Cosserat continuum with constrained particle rotation (pseudo-continuum). Size-dependent effects are taken into account according to the modified moment theory of elasticity, as well as according to the gradient theory of elasticity. Elastic-plastic deformations are taken according to the deformation theory of plasticity, the material properties depend on temperature and radiation exposure. The dependence of the stress intensity on the strain intensity, taking into account the temperature field, was obtained experimentally.

Introduction

The main structural elements of nanoactuators and nanosensors are beams (cantilever beams, rigidly clamped at both ends). During operation, space objects are exposed to the temperature field and neutron irradiation.

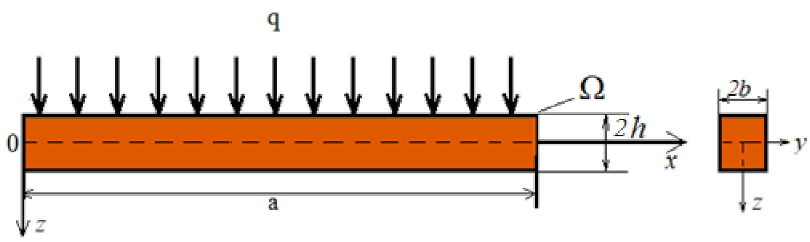

Figure 1: Scheme nanobeam.

Results and discussion

The motion equations in partial derivatives of a beams element, the boundary and initial conditions are obtained taking into account the Euler-Bernoulli hypotheses and geometric nonlinearity in the T. von Karman form from the Hamilton energy principle. The nonlinear partial differential equations system reduces to the Cauchy problem by the finite differences method of the second order accuracy in spatial coordinate. The methods convergence is studied, namely, the finite difference method depending on the number of partitions along the beam length. The Cauchy problem is solved by several methods: the Runge-Kutta type methods from second to eighth orders accuracy and the Newmark method to confirm results reliability. The results analysis is carried out by means of nonlinear dynamics and the qualitative theory of differential equations. Signals, phase portraits, Fourier power spectra, and wavelet spectra are constructed. The chaotic oscillations type analysis is carried out according to the chaos criterion given by Gulik, and also 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. The influence of the temperature field and radiation exposure on the NEMS / MEMS beam element nonlinear dynamics is shown. The effect of radiation on the beam natural frequency is investigated. The theory, algorithms and numeric experiment are obtained for the first time for beams according to the modified moment theory [1-2].

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References

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