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NONLINEAR VIBRATION OF FUNCTIONALLY GRADED REINFORCED COMPOSITE BEAMS

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Introductions. Due to their exceptional mechanical, thermal and electrical properties, high-performance fiber reinforced composites are considered as ideal reinforcement materials. Structural applications of carbon fiber reinforced composites may include parts related to various industrial applications that require a material with high strength, stiffness and low weight. A significant amount of research has been devoted to the mechanical properties of composite structures [1]. Functionally graded materials are a class of new materials with properties that vary spatially according to a given non-uniform distribution of the reinforcement phase [2]. A number of experimental and analytical studies are devoted to the study of nonlinear free and dynamic stability of composite beams [3]. It was found that the natural frequencies and excitation frequencies of beams with symmetrical distribution of mechanical load are significantly higher than those of beams with uneven and asymmetrical distribution of load. A two-stage perturbation method was used to analyze the linear and nonlinear free vibration, nonlinear bending, thermal buckling and thermal post-buckling behavior of simply supported beams lying on a linear elastic foundation [4]. Free vibrations and buckling conditions of composite beams resting on a linear elastic foundation can be determined using the generalized differential quadrature method. Most of the studies have been devoted only to the mechanical behavior of beams supported on linear elastic foundations. However, with increasing applied external load, the transverse deflection of the beam will affect the axial force, and the resulting governing equations will become coupled and nonlinear. In this case, the linear elastic soil model is insufficient to describe the real behavior of the foundation, and therefore, the use of a more complex nonlinear model becomes inevitable.

Aim. In this paper, the Haar wavelet method was used to analyze the nonlinear behavior of beam vibrations in a thermal environment. The model calculations assumed that the composite beam under consideration is fixed on a three-parameter nonlinear elastic foundation with cubic nonlinearity and a shear layer. The research plans also included the calculation of the mechanical stress field in the local volume of the sample, which is subjected to a uniform increase in temperature. Based on the first-order shear deformation theory in combination with the von Karman nonlinearity, the nonlinear governing equations of the beams are derived using the Hamilton principle. -e the resulting governing equations and the corresponding boundary conditions are first discretized into nonlinear algebraic equations using wavelet transforms and then solved by the direct iteration method to obtain the linear and nonlinear frequencies of the beams.

Materials and methods. The working body in the calculation model was a beam, which rested on a three-parameter nonlinear elastic foundation with cubic nonlinearity and a shear layer. The supporting surface of the nanocomposite beam was taken in its mid-plane, where the orthogonal coordinate system with the origin at one end of the beam was fixed. It is assumed that the nonlinear elastic foundation consists of massless springs with shear interaction between the beam and them. Based on the first-order shear beam theory, the beam displacement field was expressed in terms of the nonlinear von Karman strain-displacement relations. The body flux was determined based on the Haar wavelet discretization method. A necessary condition for the simultaneous determination of mechanical and thermal characteristics of the reinforced composite was the limited number of members of the Haar wavelet series.

Results and discussion. Parametric studies revealed a significant influence of the volume fraction of local mechanical stresses and the type of boundary condition on the flexibility coefficient and elastic foundation coefficients. The presence of a nonlinear elastic foundation was a sufficient condition for the occurrence of nonlinear oscillations in the volume of the composite structure. The presence of linear intervals of the fundamental frequency was determined by the nature of the change in the dimensionless amplitude of oscillations with different types of thermal load distribution in the reinforced composite, as well as different boundary conditions. The nonlinear frequency ratio increases with the growth of the oscillation amplitude, demonstrating the well-known behavior of the vibration of a "rigid spring". The composite beam with the boundary condition of the second type leads to the maximum linear fundamental frequency.

Conclusions. The improved computational model allowed to analyze the nonlinear behavior of oscillations of composite beams, which rested on a nonlinear elastic foundation in a thermal environment. Modeling of kinematic relations was carried out using the von Karma method. The wavelet transform method allowed to carry out a detailed description of both local thermal stress and temperature dependence of the material properties. were considered in the theoretical modeling. Numerical intervals for linear and nonlinear natural frequencies were obtained using the Haar wavelet method.

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