The effect of boundary conditions on nonlinear vibrations of plates on a viscoelastic base via the fractional calculus standard linear solid model

Marina V. Shitikova and **Anastasiya I. Krusser**

Research Centre on Dynamics of Solids and Structures, Voronezh State Technical University, Voronezh, Russia

Abstract. In the present paper, the problem of nonlinear vibrations of an elastic plate on a viscoelastic foundation with various boundary conditions is studied. The damping features of the viscoelastic foundation are described by the fractional derivative standard linear solid model. Assuming that only two natural modes of vibrations strongly coupled by the internal resonance are excited, the method of multiple time scales in conjunction with the expansion of the fractional derivative in terms of a small parameter has been utilized for solving nonlinear governing equations of motion. The governing set of equations are obtained for determining of nonlinear amplitudes and phases in the case of free vibrations of the plate for different types of boundary conditions.

Introduction

The dynamic response of plates on a viscoelastic foundation has been deeply investigated in the last few decades. In order to describe the properties of the foundation, different models of viscoelasticity are used [1]. Nowadays, the fractional calculus plays an important role in solving problems of structural mechanics [2], thereby the fractional derivative Winkler-type or Pasternak-type models of viscoelastic foundations are becoming increasingly widespread. The dynamic problems considering time-dependent properties of the material of the plate or foundation are usually restricted to simply supported plates [3]. However, in the literature there are solutions for rectangular plates with different combinations of simple boundary conditions (i.e., either clamped (C), simply supported (SS), or free (F)) [4]. Thus, Amabili et al [5] performed calculations of nonlinear frequencies of vibrations of rectangular plates for three different types of boundary conditions (B.Cs). The dynamic response of thin plates resting on a fractional derivative Kelvin-Voigt viscoelastic foundation subjected to a moving point load is investigated in [6] for four types of boundary conditions. Semi-analytical solutions and comparative analysis of natural frequencies and midpoint displacements for vibration of the viscoelastic Kirchhoff–Love plate on the Kelvin-Voigt viscoelastic foundation with various B.Cs are presented in [7]. However, the influence of boundary conditions on the nonlinear dynamic response of plates on the fractional derivative foundation accompanied by the internal resonance has not been studied.

Results and Discussion

The main purpose of the present research is to study the effect of various boundary conditions on the free nonlinear vibrations of a von Karman rectangular elastic plate resting on a viscoelastic Winkler-type foundation, the damping features of which are described by the fractional derivative standard linear solid model. The method of multiple time scales in conjunction with the expansion of the fractional derivative in terms of a small parameter [8] has been utilized for solving nonlinear equations of motion with four different types of boundary conditions. The governing equations are obtained for determining of nonlinear amplitudes and phases in the case of free vibrations, when the natural frequencies of the two dominant vibration modes are close to each other. The influence of various boundary conditions on the process of vibrations under the condition of the one-to-one internal resonance is considered and analyzed.

References

[1] Younesian D. (2019) Elastic and viscoelastic foundations: a review on linear and nonlinear vibration modeling and applications. *Nonlinear Dyn* **97**: 853–895.

[2] Rossikhin Yu.A., Shitikova M.V. (2010) Application of fractional calculus for dynamic problems of solid mechanics: Novel trends and recent results. *Appl. Mech. Rev* **63**:010801.

[3] Zamani H.A. (2020) Free vibration of viscoelastic foam plates based on single-term Bubnov–Galerkin, least squares, and point collocation methods. *Mech Time-Depend Mat* 10.1007/s11043-020-09456-y.

[4] Leissa A.W. (1969) Vibration of plates. Scientific and Technical Information Division, Office of Technology Utilization, NASA, Washington, D.C.

[5] Amabili M. (2004) Nonlinear vibrations of rectangular plates with different boundary conditions: theory and experiments. *Comput. Struct* **82(31)**:2587–2605.

[6] Praharaj R., Datta N. (2020) Dynamic response of plates resting on a fractional viscoelastic foundation and subjected to a moving load. *Mech. Based Des. Struc* 10.1080/15397734.2020.1776621.

[7] Kiasat M.S., Zamani H.A., Aghdam M.M. (2014) On the transient response of viscoelastic beams and plates on viscoelastic medium. *Int. J. Mech. Sci* **83**:133-145.

[8] Shitikova M.V. (2020) The fractional derivative expansion method in nonlinear dynamic analysis of structures. *Nonlinear Dyn* **99**:109-122