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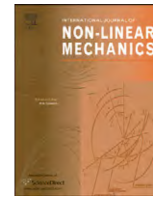

Non-linear principal resonance of an orthotropic and magnetoelastic rectangular plate

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ABSTRACT

Based on the von Karman plate theory of large deflection, we have derived a non-linear partial differential equation for the vibration of a thin orthotropic plate under the combined action of a transverse magnetic field and a transverse harmonic mechanical load. The influence of the magnetic field is due to the magnetic Lorentz force induced by the eddy current. By employing the Bubnov–Galerkin method, the non-linear partial differential equation is transformed into a third-order non-linear ordinary differential equation. The amplitude-frequency equations are further derived by means of the multiple-scale method. As numerical examples for an orthotropic plate made of silver, the influence of the magnetic field, orthotropic material property, plate thickness, and the mechanical load on the principal resonance behavior is investigated. The higher-order effect and stability of the solution are also discussed.

1. Introduction

Magnetoelastic (ME) structures have been widely used in various high technology apparatus and equipments. Due to the inherent non-linear characteristics and the multi-physics coupling effect in these structures, certain complicated static and dynamic phenomena have been observed [1,2]. The ME structure often experiences large deformation and vibration when a strong magnetic field and/or mechanical excitation are applied during the process of manufacturing or when the structure is in service. Since the ME plate plays a significant role in these structures, it is crucial to understand its non-linear vibration characteristics.

For a thin plate under large deformation, Nayfeh and Mook [3], Sathyamoorthy [4], and Yang and Sethna [5] studied the non-linear dynamic behavior of isotropic plates under various parametric loadings. Nayfeh and Pai [6] investigated the planar and non-planar responses of a non-extensional cantilever beam, and found that the hardening effect and non-planar responses for all modes were due to the non-linear geometric terms involved. Furthermore, vibration of orthotropic plates resting on elastic foundations with classical boundary conditions and elastically restrained edges was thoroughly analyzed [7,8]. Moorthy et al. [9] investigated the parametric instability of laminated composite plates with transverse shear deformation subjected to uniaxial harmonic loading using the finite element method. Udar and Datta [10] studied the resonance characteristics of simply supported laminated square plates subjected to non-uniform and concentrated edge loading. Shih and Bloter [11] analyzed the non-linear vibration of laminated thin rectangular plates on an elastic foundation and discussed the influence of the excitation amplitude, material lamination, and boundary conditions on its non-linear frequency. Hsu [12] studied the vibration response of orthotropic plates on non-linear elastic foundations using the differential quadrature method.

With regard to the non-linear analysis of magnetoelastic structures, Moon and Pao [13], and Pao and Yeh [14] studied the magnetoelastic vibration of a ferromagnetic cantilever beam under a magnetic field. Recently, Hasanyan et al. [15] proposed a mathematical model for the non-linear vibration of a conductive plate under an inclined magnetic field. Librescu et al. [16] studied the geometric non-linearity of elastic isotropic plates subjected to an external magnetic field. Belubekyan et al. [17] presented the magnetoelastic vibration of a flat plate immersed in an external magnetic field and found that the localized bending vibration can be eliminated by means of an applied magnetic field. Hu et al. [18]

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