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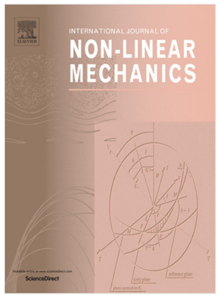


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# Nonlinear vibration of a rotating cantilever beam in a surrounding magnetic field

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**Abstract** The nonlinear vibrations of a rotating cantilever beam made of magnetoelastic materials surrounded by a uniform magnetic field are investigated. The kinetic energy, potential energy and work done by the electromagnetic force are obtained. A nonlinear dynamic model, based on the Hamilton principle, which includes the stretching vibration and bending vibration is presented. The Galerkin method is adopted to discretize the dynamic equations. The proposed method is validated by comparison with the literature. The nonlinear behaviors of the responses are studied. Then simulations for different kinds of magnetic field are conducted. The effects of magnetic field parameters, including the amplitude, plane angle, spatial angle and time-varying frequency, on the dynamic behaviors of the stretching motion and bending motion are investigated in detail. The results illustrate that the interaction effects between the rotating cantilever beam and the magnetic field will increase the vibration amplitude and fluctuation of the beam. In particular, we found that: collinear magnetic fields with equal amplitude lead to the same dynamic responses; the amplitude of magnetic field intensity increases the dynamic responses remarkably; the response amplitude changes nonlinearly with the plane angle and spatial angle of the magnetic field; and the increase of time-varying frequency enhances dynamic responses of the rotating cantilever beam.

**Keywords**: nonlinear vibration; magnetic field; interaction; rotating cantilever beam

## 1.Introduction

In the space exploration industry, rotating beams are of great importance in engineering applications such as aircraft rotary wings, helicopter rotor blades, spacecrafts with flexible appendages, etc. Modeling issues of rotating beams are interesting research topics and have been investigated extensively. Liu and Hong [1] proposed the early linear modeling method and ignored the longitudinal deformation. Kane et al. [2] presented some simulation results of the linear model for structures with large overall motions. Since then, much work [3, 4] has been dedicated to modeling the geometric stiffening effect. Among them, Yoo et al. [3] made an improvement by taking the motion-induced stiffness into account. In the last decade, many dynamic models which included the stiffening and Coriolis effects due to beam rotation had been presented. The modeling methods may be classified into three categories. The elastic deformation described in the first category [5-7] is based on the hybrid set of deformation variables which consist of a non-Cartesian variable (stretch deformation) and two Cartesian variables (chordwise and flapwise deformations). In the modeling methods of the second category [8-10], the authors took the stiffening effect of a beam into account by adding the elastic potential energy resulting from centrifugal force to the total potential energy. In order to consider the stiffening effect of rotating beams, the authors in the third category [11-13] used the nonlinear strain or stress.

Although investigations about rotating beams are extensive, the working conditions rarely involve a magnetic field. With the development of modern aerospace technology, traditional metallic material cannot meet the needs of practical applications. A key progress may depend on the adoption of smart materials including soft ferromagnetic material or magnetoelastic material. The latter material shows great ability in energy conversion and is suitable for application in actuating devices, vibrations control and energy harvesting etc. The conventional material in beam structures is being increasingly replaced by the magnetoelastic material. The magnetic field is almost everywhere with the popularity of numerous electromagnetic devices.