Application of a hybrid method to the nonlinear dynamic analysis of a flexible rotor supported by a spherical gas-lubricated bearing system

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Abstract

This paper employs a hybrid numerical method combining the differential transformation method and the finite difference method to study the nonlinear dynamic behavior of a flexible rotor supported by a spherical gas-lubricated bearing system. The analytical results reveal a complex dynamic behavior comprising periodic, sub-harmonic, and quasi-periodic responses of the rotor center and the journal center. Furthermore, the results reveal the changes which take place in the dynamic behavior of the bearing system as the rotor mass and bearing number are increased. The current analytical results are found to be in good agreement with those from other numerical methods. Therefore, the proposed method provides an effective means of gaining insights into the nonlinear dynamics of spherical gas film rotor–bearing systems.

Keywords: Differential transformation method; Spherical gas bearing; Reynolds equation

1. Introduction

Gas film bearing–rotor systems are ideally suited for use in precision instrumentation due to their low noise during rotation and their zero friction when the instruments are used as null devices. In 1961, Gross [1] presented perturbation solutions for steady, self-acting, infinitely long journals and plane wedge films. The perturbation solutions were valid for all ranges of geometrical parameters and were highly accurate. Castelli and Elrod [2] presented a method for solving the stability problem in 360-degree self-acting, gas-lubricated bearing systems. The proposed method involved integrating a set of nonlinear equations to obtain the rotor center orbits corresponding to any set of geometrical, operating or initial conditions.

In 1978, Holmes et al. [3] conducted an investigation into aperiodic behavior in short journal bearings. The authors concluded that moderate levels of imbalance and a high eccentricity ratio led to an aperiodic response of the shaft at speeds above a critical threshold value. Sykes and Holmes [4] performed experimental observations of sub-harmonic motion in squeeze film bearings and suggested that this motion was a possible precursor of chaotic motion. Kim and Noah [5] analyzed the bifurcation of a modified Jeffcott rotor using the bearing clearance as the bifurcation parameter.