Nonlinear dynamics analysis of rotor-active magnetic bearings system

Zhang Xiaoshen, Fan Tianpeng, Sun Zhe, Zhao Lei, Shi Zhengang

Institute of Nuclear and New Energy Technology of Tsinghua University, Beijing, China

Collaborative Innovation Center of Advanced Nuclear Energy Technology, Beijing, China

Key Laboratory of Advanced Reactor Engineering and Safety of Ministry of Education, Beijing, China

Compared with conventional rolling bearings and journal bearings, active magnetic bearings(AMBs) have a number of advantages, such as no mechanical touch, no wear, lubrication free, etc. Especially, rotor dynamic behaviors could be controlled actively through AMBs. However, since most components in AMBs are of nonlinear characteristics, AMB system exhibits a variety of nonlinear phenomena, such as, bifurcations, jump phenomena, multi-value solutions, chaos and sensitivity to initial conditions, etc. The dynamic behaviors of rotor-AMBs system are so complicated that the accuracy of the simple linear model of the rotor-bearings system is not enough for industrial application sometimes. So it is crucial to investigate nonlinear dynamic responses of the system.

In this paper, the nonlinear dynamics analysis of a single-degree-of-freedom rigid rotor-AMBs system was carried out. In AMB system, the electromagnetic force is a nonlinear function with respect to control current and displacement of the rotor. This paper proposed a mathematical model of the system with taking the nonlinearity of electromagnetic force into account and then in order to get intuitionistic graphics, dimensionless nonlinear governing equations of the system were obtained. The numerical simulations were performed for analyzing the nonlinearities of the system in which bifurcation diagrams, trajectories, power spectra and Poincare maps were used to analyze the dynamic behaviors of the rotor-AMBs system under different operating conditions. The key system parameters which affect the dynamic characteristics of the rotor were identified in this paper and the influence of system parameters like the magnitude of external excitation, proportional gain, differential gain, and initial condition on the rotor dynamics was illustrated. The study shows that the nonlinearity of electromagnetic force has key effects on the dynamic characteristics of the rotor-AMBs system and there are various nonlinear phenomena in the system.