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Identification of rod dynamics under influence of Active Magnetic Bearing

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ABSTRACT

The purpose of this paper is to apply the wavelet transform algorithm to identify the magnetic damping and magnetic stiffness coefficients of the drive rod with which a set of 4-pole Active Magnetic Bearing (AMB) is equipped. By taking advantage of time–frequency analysis feature, the ridge curve of rod free response after wavelet transformation can be extracted to find the natural frequency of the rod/AMB system. In other words, due to the influence of magnetized field by the AMB, the stiffness of the rod dynamics is not linear any more and can be estimated from the curve of the amplitude versus frequency by wavelet transformation. On the other hand, the nonlinear damping coefficients can be estimated from the derivative of amplitude versus amplitude by wavelet transformation of rod free vibration. It is found that the nonlinear magnetic damping coefficients are up to 2nd-order in polynomial and the stiffness coefficient is mainly of 3rd-order respectively. In addition, the identified 2nd-order damping coefficient is negative and hence implies that under specific rod displacement and speed, the dynamic of the rod/AMB system in axial direction is unstable.

1. Introduction

Due to the overwhelming evolution of the semiconductor industries, high quality, clean environment and high productivity are certainly required. Conventionally, the particles and the noise are generated by the mechanical friction and the vibration of the machine operation. In order to account for these impacts, the Active Magnetic Bearing (AMB) is employed to reduce friction and vibration [1–7]. The major merits of the magnetic levitation system are: free of lubrication, free of mechanical wear and free of noise. Due to these unique properties, AMB have been popularly utilized in numerous fields, instead of merely semiconductor sector. For example, high-speed spindles employed for milling machines and multi-stage centrifugal compressors, whose rotors are supported by magnetic bearings, have been reported [8,9]. However, the dynamics of AMB-embedded system becomes more complicated, owing to the magnetic nonlinearity property. Therefore, how to establish the mathematical nonlinear system model or identify the system parameters is significant.

As to the magnetic parameters identification for AMBs, there are many methods which have been successfully developed to determine the damping coefficients and the stiffness coefficients. By experimental approach, the nonlinear magnetic coefficients of the AMB can be directly identified from the experimental input/output data so that the dynamic model of the entire AMB-embedded system can be reconstructed [10–12]. By Eigen-system Realization Algorithm (ERA) approaches, Chen adopted to identify the stiffness and damping parameters of the linearized rod/AMB system [13]. For clustering-based hybrid evolutionary algorithm, Kim et al. proposed a methodology which can identify not only unknown bearing parameters but also the unbalance information [14]. By frequency-domain control-relevant identification, Ahn et al. identified an approximate MIMO (Multiple-Input Multiple-Output) model in matrix fractional description [15]. Based on the identified model, the LQG/LTR controller is designed to moderately enhance the performance of the MIMO rotor/AMB system. By least mean square algorithm, Kim et al. identified the stiffness of an AMB system equipped with four pairs of built-in radial magnetic force transducers [16]. Their algorithm is based on a simple linear relation between the electromagnetic force, control current and stiffness. However, all the aforesaid identification algorithms on AMB are aimed at the rotary systems. The identification method for the AMB embedded in translational machines has not been reported yet.

In this paper, the nonlinear magnetic damping and magnetic stiffness coefficients for the linear compressor system by the wavelet transform algorithm is proposed and verified. Firstly, the motional characteristic of the linear compressor system with respect to the magnetic attractive force provided by the AMB (Active Magnetic Bearing) is analyzed by employing commercial software, *Ansoft Maxwell*. In Section 4, the numerical examples of two 2nd-order mathematic nonlinear models are identified by

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