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ScienceDirect

Procedia Technology 23 (2016) 106 – 113

Procedia Technology

3rd International Conference on Innovations in Automation and Mechatronics Engineering, ICIAME 2016

Controllability of Radial Magnetic Bearing

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Abstract

The magnetic bearing works on the principle of magnetic levitation. Integration of the geometric and control designs is the current trend in mechatronic products. Conventionally, in control of rotors in the vertical direction, it must be supported at two places by radial magnetic bearings. A thrust magnetic bearing is also provided to prevent axial movement of the shaft. In the present work, control design methodology of four pole pair active magnetic bearings has been proposed. This work is dealing with the modeling, investigations and controlling of radial magnetic bearing system. Considerations based on the four pole pair's model with switched mode power supply. Investigations of radial forces in two axes model and performance response are carried out through the PID controller system. The response is presented for standstill and dynamic conditions using the implemented Simulink software. Simulation results showed that rotor is in standstill position with constant air gap of 1mm. This validates bearing design dimensions and system parameters designed for control of four pole pair radial magnetic bearing considering 1mm air gap length.

Peer-review under responsibility of the organizing committee of ICIAME 2016

Keywords: Magnetic levitation; electromagnetic forces; motion control; Radial magnetic bearing.

1. Introduction

The first application of magnetic levitation using active control of current in electromagnet was proposed by Kemper in 1934. Later in 1960's the principle of levitation was attempted to support a rotating shaft. Tadashi Sato, Yarimoto Tanno [1] described combined PID discontinuous controllers that reduce the electrical power loss in magnetic bearing. Sriram Srinivasan, Young Man Cho [2] carried out modelling and system identification of active magnetic bearing. Mukhopadhyay, Ohji, et al.[3] worked on the development of a new repulsive type magnetic bearing system whose radial bearing section makes good utilization of the repulsive forces between stator and rotor permanent magnets resulting a simplified axial control scheme. Matti Antila, Erkki Lantto and Antero Arkkio[4]

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Peer-review under responsibility of the organizing committee of ICIAME 2016
doi:10.1016/j.protcy.2016.03.005

uses a nonlinear two-dimensional (2-D) finite element method (FEM) to predict the performance of radial magnetic bearings.The force calculations based on the finite element method are verified by measurements with two machines equipped with active magnetic bearings. Isaias da Silva and Oswaldo Horikawa[5] presents the principle, the dynamic model of new type magnetic bearing with active control only for axial motion and the control system for this bearing are presented. Kim and Kim [6] developed a centrifugal blood pump with a magnetically suspended impeller to reduce the haemolysis level for long-term use. The main advance made was simplifying the traditional 5-axes controlled magnetic bearing system, since the total device should ultimately be small enough to implant into a human body.

Norbert Skricka and Richard Markert [7] presented two aspects of the integration of electromagnetic bearings. The non-linearity of the magnetic force is compensated by software integrated in the digital controller. In self-sensing bearings the rotor position is identified from the electric state variables directly at the power amplifiers. Polajzer, Ritonja, Stumberger, et al.[8] discusses a closed-loop decentralized control for active magnetic bearings(AMB). A cascade connection of PI and PD position controllers is proposed. Jiang, Wu, Lu and Li[9] developed a new method and find a mathematical model that aims to research the controllability of AMB. The stiffness and damping of AMB, which changes randomly along with the rotor running, are determined by the controller system. Hung-Cheng Chen, Sheng-Hsiung Chang [10] suggested a fine-tuning technology for optimal design of a PID controller of an AMB based on genetic algorithms. Peijnenburg, Vermeulen and Eijk[11] describes the development of a full 6-DoF active positioning system with nm-level motion performance in one single (long stroke) stage, using active magnetic bearing systems. Naseer Hamoody and Adil Ahmad[12] presents a work is dealing with the modelling, investigations, and controlling, of a prototype of eight pole radial magnetic bearing system. The response is presented for standstill and dynamic conditions using the implemented Simulink software. Rao and Tiwari [13] studied two different bearing geometries with different operating parameters and optimal design methodology of double-acting hybrid active magnetic thrust bearings has been proposed. Double-acting actuators and controller are optimized as a unified system. Santosh shelke[14] has presented study of theoretical design of varying pole pair radial magnetic bearing(RMB) considering 0.5mm air gap length and optimum losses are found in four pole pair RMB using genetic algorithm.

The review of the past literature ravealed that considerable amount of work is still required to study the control aspects of four pole pair radial magnetic bearing. Hence, in this work it is attempted to look for modelling, formulation and system response which are shown in section (2, 3). Further an analysis of four pole pair radial magnetic bearing was performed considering PID controller, simulink results and conclusions are detailed in sections (4, 5).

The basic layout of a magnetic bearing system is shown in Figure1. Stationary electromagnets are positioned around the rotating assembly of a machine.

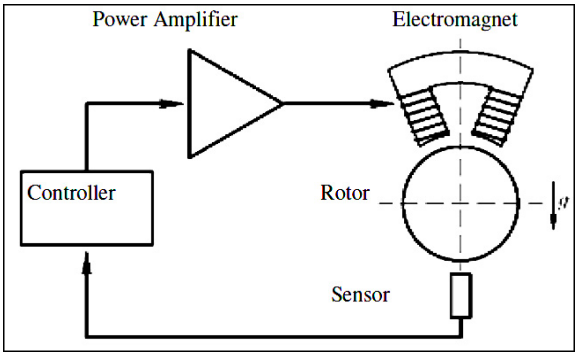

Fig 1. Working principle of the Radial Magnetic Bearing

Typically, two radial magnetic bearings are used to support and position the shaft in the lateral (radial) directions and one thrust bearing is used to support and position the shaft along the longitudinal (axial) direction. When the magnetic bearing is operating, each magnetic bearing rotor is ideally centred in the corresponding stator so that contact does not occur. The position of the shaft is controlled using a closed-loop feedback system. The position