

Summary

Magnetic bearings provide contactless rotor support by exploiting magnetic forces, eliminating mechanical contact between moving parts. The absence of physical contact results in negligible friction and wear, removes the need for lubrication, and significantly reduces maintenance requirements, enabling high rotational speeds, improved efficiency, and reliable operation in harsh environments. Among the existing magnetic bearings, passive magnetic bearings of permanent magnet type provide force and stiffness while avoiding the complexity of active systems and other operational constraints, thus representing an attractive solution for low-maintenance and energy-efficient rotor applications.

This doctoral thesis investigates the modelling of passive magnetic bearings of permanent magnet type and the dynamic behaviour of rotor systems supported by these devices. The work aims to describe the mechanisms governing force and stiffness characteristics, as well as damping effects, and to assess their influence on the rotordynamic response and stability of such systems.

In the existing literature, passive magnetic bearings are commonly modelled using constant force and stiffness coefficients, thereby neglecting their dependence on the relative position between rotor and stator, as well as the effects of electromagnetic interactions with conductive components.

To overcome these limitations, this thesis introduces a numerical magnetostatic modelling approach that accounts for the variation of magnetic forces and stiffness with radial and axial offsets between the rotor and stator rings.

In addition to magnetostatic effects, the work addresses electrodynamic phenomena associated with eddy currents induced in conductive components subjected to time-varying magnetic fields. An electrodynamic model, based on finite element analysis, is developed to describe damping mechanisms arising from both rotating and nonrotating contributions. These effects introduce energy dissipation mechanisms that depend on rotational speed and rotor position and therefore cannot be adequately captured through simplified constant damping models.

The magnetostatic and electrodynamic models are consistently integrated into a comprehensive rotordynamic model that incorporates nonlinear forces and stiffness, and eddy current induced damping within the equations of motion. This approach enables the analysis of the dynamic response, stability limits, and energy

dissipation characteristics of rotor systems supported by passive magnetic bearings. Experimental campaigns are conducted on two dedicated rotor prototypes to test the proposed modelling framework. A rotor system equipped with thrust–radial passive magnetic bearings is used to investigate the position-dependent nonlinear characteristics of magnetic forces and stiffness and to analyse their influence on the dynamic behaviour and power loss reduction. A second rotor prototype, supported by a single passive magnetic bearing, is employed to investigate the electrodynamic damping and to experimentally demonstrate the occurrence of transitions to unstable dynamic regimes under specific operating conditions.

The comparison between experimental results and model predictions shows that the proposed approach captures position-dependent dynamic behaviour and stability thresholds, and provides design criteria for passive magnetic bearing configurations capable of providing both radial and thrust support while reducing power losses.