LPV CONTROL OF A MAGNETIC BEARING EXPERIMENT

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***Abstract*— An LPV (Linear Parameter Varying) controller design example for a Magnetic Bearing System is presented. A linear model of the system including bending modes and imbalance is described. Simulations and experimental results show the usefulness of the LPV method with eigenvalue clustering constraints in spite of the limited rotation rate range. The results show that this method facilitates simulation and allows implementation. Conclusions are drawn on the limited range for the rotation rate the LPV controller allows for.**

***Keywords*— Magnetic Bearings, LPV Control.**

I. INTRODUCTION

In this work an LPV approach has been used in order to design the control of an Active Magnetic Bearing (AMB) system of an MBC500 experimental magnetic bearing system. The MBC500 is a product designed and manufactured for academic research by *Magnetic Moments*, a division of *LaunchPoint Technologies, LLC* (see Paden *et al.* (1996) for a detailed description and the company's website: http://www.launchpnt.com). The particular MBC500 used for the experiments includes the "Turbo 500" option which allows for controlled rotation of the beam.

The addressed control problem deals with the stabilization of the machine's rotating shaft. No matter how well balanced the rotor may be, there is always an uncertain amount of eccentricity in it. This means that the axis of inertia is not exactly the geometric one, and as a result, imbalance forces appear. As a consequence controlling the vibration of the rotor due to imbalance is within the main goals.

In practice, imbalance can be modeled as "external" forces representing the eccentricity, while considering the rotor as a rigid body with its inertia and geometric axis being the same. As functions of time, these forces are considered sinusoidal (while the machine rotates), with uncertain but bounded magnitudes and phases, and measurable frequency (rotor's rotating speed).

This work was originally motivated by the problem solved in Matsumura *et al.* (1996). In that paper, a gain scheduled loop–shaping $\mathcal{H}_\infty$ control for a motor with magnetic bearings is developed.

In this paper, which is a continuation of the work presented in Ghersin *et al.* (2007), especially as the experimental results are concerned, we have considered the use of LPV control for this kind of application. This allows us to take into account parameter varying nature of the system's dynamics. The uncertainty due to high order bending modes of the rotor has been considered as well.

When the scheduling parameters enter affinely into the system matrices, a simplified version of LPV controllers can be designed Becker and Packard (1994). Considering the range of parameter variations as an hypervolume defined by its vertices this methodology solves the controller in terms of a finite number of "vertex" controllers. The controller is computed as a convex combination of the vertex controllers giving a smooth scheduling as the parameter changes. In the sequel, "parameter" will be taken as parameter vector. These results will be discussed in the following section.

To address robustness concerns, the modelling approach is intended to deal with the flexible dynamics of the MCB500's rotor, covering them with global dynamic uncertainty frequency bounds. Simple experimental tests have shown that due to the limited bandwidth of the current amplifier of the system, only the first two bending modes of the rotor show up in the responses of the system to sinusoidal signals introduced at the voltage control inputs of the current amplifiers.

A practical problem which appears in the design of LPV controllers, is the presence of fast dynamics, which appear as fast poles for each frozen LTI system in the parameter variation set. This imposes implementation restrictions and significantly increases the burden of simulation. This problem was previously addressed in Ghersin and Sánchez Peña (2002). A survey of this technique, which is basically an extensions of the results of Chilali and Gahinet (1996) to LPV systems, has been given in Ghersin *et al.* (2007). The results are briefly discussed in the following section.

II. SYNTHESIS METHOD

The existence of a symmetric positive definite matrix X such that given a square matrix A, a Lyapunov inequality of the form $A^TX + XA < 0$ is satisfied, is a means to guarantee that all the eigenvalues of A are in a certain