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1 Introduction

In our modern society there is an ever increasing need for higher computational power and storage capacities together with a reduction at the production costs. In the semiconductor industry, these demands are translated into an effort to achieve a larger wafer size and a smaller circuit detail, from the scale of 30nm down to 5nm, together with an increase in the positioning speed. The transition from dual-stage positioning systems [1] to a magnetically levitated planar actuator is necessary towards the successful implementation of the concept. However, the nonlinear position- and velocity-dependent electromagnetic interaction between the translator and the coils as well as deformation due to thermal effects and the high accelerations of the translator restrict the performance capabilities of this approach.

In this research we will introduce a Linear Parameter Varying (LPV) framework to model these effects and capture the unknown relations in terms of a low complexity model by using a data driven modelling approach. By making use of this model we will synthesize controllers that can attenuate these dynamical aspects and realize the intended high accuracy behaviour of the magnetically levitated positioning system under high throughput demands. The LPV framework is capable of capturing position dependent and nonlinear behaviour, nonstationary characteristics or dependence on external variables by employing a low complexity model, which is achieved by capturing these effects in terms of scheduling variables that are assumed to be measurable in the system.

2 Modelling and identification of planar motor system

Modelling the magnetically levitated planar motor requires the derivation of an analytic description of the underlying mathematical relations. For this reason a multi-physical model of the motor has been already established in previous research, which entails a magnetostatic, a mechanical and a thermal model. Nonetheless, this analytic model has its own limitations due to manufacturing imperfections or unforeseen dynamics. For this reason, it is our aim to complement it by employing an LPV identification approach, since it allows for the incorporation of the position and velocity dependence in the coil-magnet interaction.

To this end, the recent developments in the machine learning community and their close interaction with system identification have proven themselves a valuable tool towards the increase of the accuracy of the estimated model. This synergy offers an increased flexibility to system identification through the use of kernel functions and it has recently been formulated to achieve data-driven LPV modelling, both within the prediction error [2] and subspace [3] context.

3 Control of planar motor system

Following the development of a reliable and low complexity LPV model of the planar motor system, in this research we will focus on controlling the planar motor in 6 degrees of freedom using LPV control techniques. Two main targets will be pursued: the efficient cancellation of the deformations in the plate due to the thermal aberrations and the asymmetric spatial distribution of the forces during high accelerations, as well as the nanometer accurate reference tracking during a high speed scanning. Due to a possibly high-dimensional model, model reduction techniques can be of use prior to the implementation of the controller. Moreover, the highly coupled nature of the system dynamics will be tackled with the use of a multiple input multiple output (MIMO) controller based on the LPV concept. The design of an LPV feedforward controller will enable the significant reduction of the error within the required margins. Finally, the feedback controller will compensate for the remaining errors due to model uncertainty. The designed controller will be experimentally validated in the magnetic planar motor prototype, which was designed and contructed in the technological university of Eindhoven [4].

References

[1] H. Butler, "Position control in lithographic equipment," *IEEE Control Systems Magazine*, vol. 31, no. 5, pp. 28–47, 2011.

[2] M. Darwish, P. Cox, G. Pillonetto, and R. Tóth, "Bayesian identification of lpv box-jenkins models," in *Proceedings of the 54th IEEE Conference on Decision and Control (CDC), Osaka, Japan*, IEEE, 2015.

[3] I. Proimadis, H. Bijl, and J. W. van Wingerden, "A kernel based approach for lpv subspace identification," in *Proceedings of the 1st IFAC Workshop on Linear Parameter Varying Systems, Grenoble, France*, 2015.

[4] J. Jansen, J. P. Smeets, T. T. Overboom, J. Rovers, and E. Lomonova, "Overview of analytical models for the design of linear and planar motors," *Magnetics, IEEE Transactions on*, vol. 50, no. 11, pp. 1–7, 2014.