On robust performance for lightly damped systems : non-normalized coprime factors and weighting function design

On Robust Performance for Lightly Damped Systems: Non-normalized Coprime Factors and Weighting Function Design

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Introduction

Next-generation high-precision positioning systems are designed to be lightweight, in order to enable an increase of the speed of movement. Lightweight systems tend to have complex dynamical system behavior at frequencies relevant for control. This flexible dynamical behavior should be explicitly addressed during controller design to i) improve robustness with respect to model uncertainty and ii) suppress undesired vibrations of the wafer stage.

Formulation optimization criterion

$\mathscr{H}_\infty$-optimization is a powerful tool for control design of complex multivariable systems, since it explicitly takes robustness into account. However, it is well known that the selected uncertainty structure determines to a large extent the distance between plants [1]. As a result, $\mathscr{H}_\infty$-optimal controllers can, for certain uncertainty structures, not be guaranteed to stabilize lightweight motion systems with respect to small variations in lightly damped flexible dynamical behavior at frequencies relevant for control, see Fig. 1.

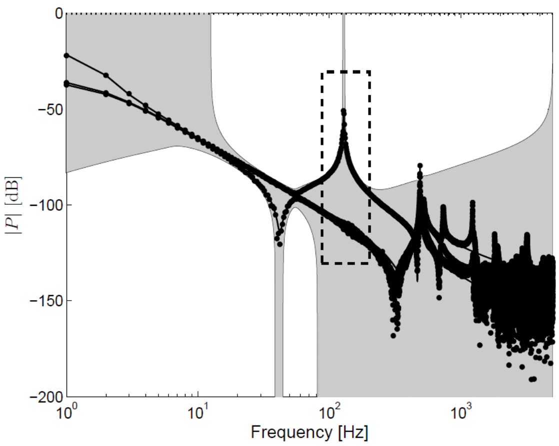

Figure 1: Bode magnitude diagram: nonparametric estimate (dot), nominal model (black) and model set (dashed).

Robustness with respect to uncertainty is a key aspect for closed-loop performance. As illustrated in [2], the freedom introduced by non-normalized coprime factor uncertainty can be exploited to improve the formulation of performance and robustness requirements in the optimization criterion. The design of weighting functions is of vital importance in the formulation of such a criterion. In this research, a first solution is provided for the formulation of weighting functions that reflect performance and robustness goals for lightly damped resonance phenomena close to the crossover region, as indicated by the dashed rectangle in Fig. 1.

Experimental results

An experimental confrontation with an industrial motion system as shown in Fig. 2 illustrates the performance enhancement resulting from the proposed weighting function design in the non-normalized coprime factor framework.

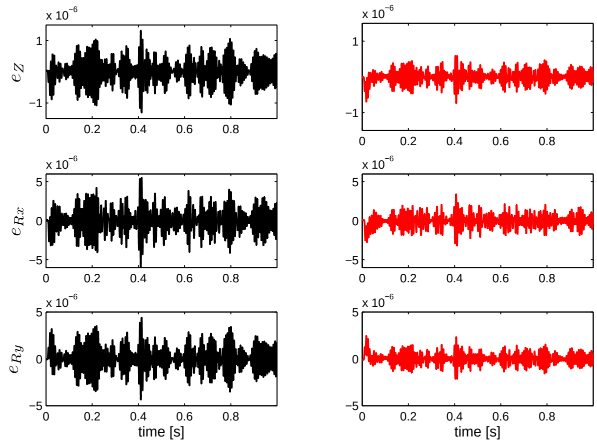

Figure 2: Measured time domain responses: controller based on classical weighting functions C^{class} (black) and C^{mimo} (red) based on the proposed multivariable weighting.

Ongoing research

Recent developments within the presented framework are aimed at controller synthesis [3] and distance measures [4]. These developments illustrate the potential of non-normalized coprime factors for an improved performance definition for complex multivariable systems.

References

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