High-performance motion control of lightweigth systems : advanced modeling

High-Performance Motion Control of Lightweight Systems: Advanced Modeling

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Description of Poster

Since lightweight systems are versatile, highly manoeuvrable and have a low energy consumption, future positioning devices, as encountered in, *e.g.*, ASML's integrated-circuit manufacturing machines, are becoming ever more lightweight. Despite of the use of advanced materials and mechatronic design configurations, lightweight systems are inevitably more flexible than conventional rigid-body systems. Flexible dynamical behaviour of lightweight motion systems manifests itself through intrinsically multivariable deformations of the system, which are detrimental for a high positioning accuracy. Hence, a multivariable compensation of these phenomena through control design is essential. This has far-reaching consequences, since manual loop-shaping techniques alone cannot provide complex multivariable controllers for multivariable motion systems. High-performance control design requires the use of advanced optimization techniques provided by, *e.g.*, model-based control design.

This poster considers two fundamental research issues, *viz.* **(I)** formulation of the control design problem, and **(II)** automated identification of highly accurate parametric models for control design.

(I) Successful synthesis of model-based controllers using automated optimization routines hinges on the formulation of a suitable performance criterion. This criterion, which takes shape through the specification of weighting filters, should (1) reflect well-known design principles that are widely applied in classical loop-shaping, but should also (2) dictate how flexible dynamical behaviour is to be addressed by the controller. Whereas it is well-understood how to dictate a desired bandwidth, as well as to enforce integral action and controller roll-off, using classical loop-shaping ideas, it is difficult to address the flexible dynamical behaviour of lightweight motion systems, due to its intrinsically multivariable character. This poster presents novel ideas for the formulation of a control problem that leads to high-performance multivariable motion controllers that provide damping of system vibrations that are detrimental for a high positioning accuracy.

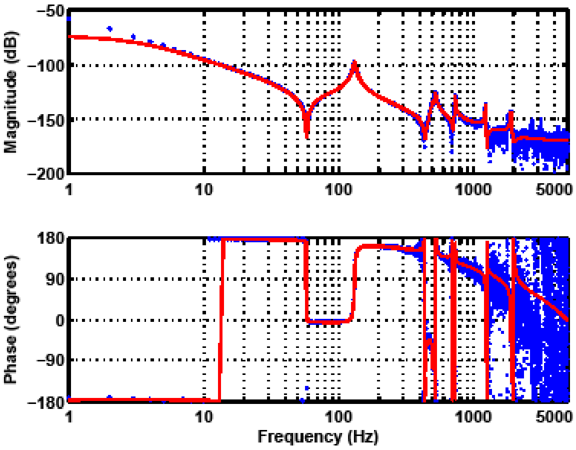

Fig.1 Application of a numerically advanced identification algorithm enables extraction of a 15th order model from a 5000 point FRF, which captures system resonances that are relevant for control design.

(II) Evidently, model-based control design requires highly accurate models of the system to-be-controlled. Yet, any model has a limited complexity. Hence, accurate modelling requires (1) automated selection of those system aspects that need to be described accurately in order to enable high-performance control design, and (2) a numerical procedure that can reliably deal with large frequency response functions (FRFs) for multivariable sytems with many inputs and outputs. This poster presents the successful application of a new identification algorithm that reveals system artefacts that are relevant for control design, far beyond what is provided by state-of-the-art modelling procedures. Figure 1 shows a typical result, obtained by application of the developed procedure to one of ASML's next-generation motion systems.

The capability of building highly accurate models in a numerically reliable and computationally efficient way, see **(II)** forms a cornerstone for successful model-based control design. It paves the way towards modelling and control of systems with many inputs and outputs. This allows for a scenario where additional actuators and sensors, beyond the conventional I/O selection for rigid-body systems, are used to actively control lightweight positioning devices. Thereto, future research is focussed on an extension of the control design formulation, see **(I)**, to accommodate for such 'overactuated' control design.