

Bandwidth increase of positioning tables

Citation for published version (APA):

Verbaan, C. A. M., Rosielle, P. C. J. N., & Steinbuch, M. (2013). Bandwidth increase of positioning tables. In *Proceedings - ASPE 2013 Spring Topical Meeting MIT Laboratory for Manufacturing and Productivity Annual Summit: Precision Control for Advanced Manufacturing Systems* (Vol. 55, pp. 76-79)

Document status and date:

Published: 01/01/2013

Document Version:

Accepted manuscript including changes made at the peer-review stage

Please check the document version of this publication:

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

[Link to publication](#)

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:

www.tue.nl/taverne

Take down policy

If you believe that this document breaches copyright please contact us at:

openaccess@tue.nl

providing details and we will investigate your claim.

BANDWIDTH INCREASE OF POSITIONING TABLES

Cornelis A.M. Verbaan¹, Petrus C.J.N. Rosielle¹, and Maarten Steinbuch¹

¹Department of Mechanical Engineering
Eindhoven University of Technology
Eindhoven, The Netherlands

HIGH-END MOTION SYSTEMS

In the industry of high-end manufacturing, for instance in the semiconductor market, various processing and measurement steps take place on positioning tables or stages. In these types of high-tech motion systems, the finite stiffness of mechanical components usually limits the bandwidth of the control system [1]. This can be counteracted by increasing the controller complexity, for instance by using notch filters [2]. The resonance frequencies of the non-rigid body dynamics and the amount of damping significantly affect the achievable bandwidth.

POSITIONING TABLES

The dynamical behavior of relatively flat positioning tables is mainly characterized by mode shapes with large out-of-plane displacements. These mode shapes are dominant in the transfer function in z-direction and limit the achievable control bandwidth in that direction. A square plate is used as an abstracted stage model. The plate's mode shapes are exported from FEM and a state space model is generated.

ADDING DAMPERS

A method is investigated to add damping to the out-of-plane flexible behavior of this square plate model, using tuned mass-dampers [3], also called harmonic absorbers. Very high local damping is applied to these dampers. The connections between the plate and the dampers are determined at the plate corners because

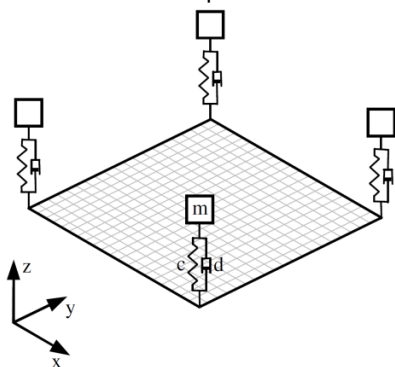


Figure 1: Model of a square plate with 4 dampers added on the corners. The DoF of the dampers is in z-direction. The four dampers have the same mass, damping and stiffness.

these locations have relatively large vibration amplitudes. See Figure 1. The mass-spring-damper system uses the plate's displacement and velocity as input and generates a damping force that acts on the plate. The damper model is also created in state space description and a superseding model is calculated for the plate with four dampers added [4].

MODAL DAMPING INCREASE

The main result is that a significant modal damping increase is achieved over a broad band of resonances, with only a small number of dampers added. This implies a small mass increase of the overall system. Decoupled transfer functions are calculated by applying a geometrical decoupling procedure. The damper parameters are tuned to suppress the bandwidth limiting resonances and therefore achieve an as high as possible bandwidth.

BANDWIDTH IMPROVEMENT

The damping increase primarily results in a control bandwidth improvement of over 150%, with the same stability margins applied during controller design. See Figure 2. A higher controller gain can be applied. This higher open-loop gain leads to a disturbance suppression increase of over 10 times for both force and displacement disturbances.

REFERENCES

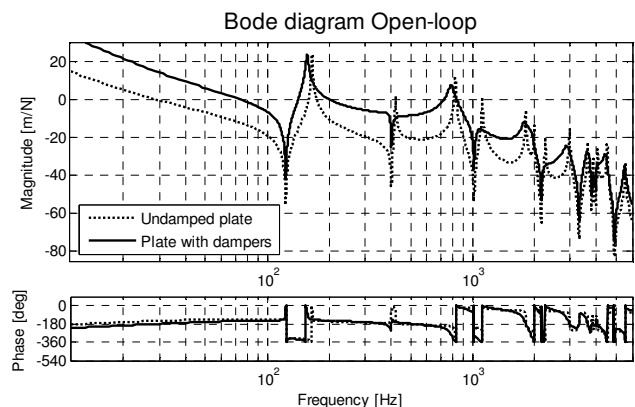


Figure 2: The dotted line represents the Bode diagram of the undamped plate and the solid line represents the transfer function of the plate with dampers.

- [1] Book, W.J., Controlled Motion in an Elastic World, Journal of Dynamic Systems, Measurement and Control, 50th Anniversary Issue, March 1993, p. 252-261
- [2] S. Skogestad and I. Postlewaite, Multivariable Feedback Control, John Wiley & sons Ltd. Chichester, 2005
- [3] S. Krenk, J. Hogsberg, Tuned Mass Absorbers on damped structures, 7th European Conference on Structural Dynamics, Southampton, 7-9 July, 2008
- [4] W.K. Gawronski, Dynamics and Control of Structures – a modal approach, Springer-Verlag, New York, 1998