DSPE YOUR PRECISION PORTAL
2020 CONFERENCE ON PRECISION MECHATRONICS
8 & 9 September - De Ruwenberg Sint Michielsgestel
www.dspe-conference.nl

# Accurate FRF identification of complex systems via multivariable experiment design

Nic Dirkx[1,2], Jeroen van de Wijdeven[1], Tom Oomen[2]

[1]*ASML Research Mechatronics & Control, Veldhoven, The Netherlands*
[2]*Eindhoven University of Technology, Department of Mechanical Engineering, Control Systems Technology, Eindhoven, The Netherlands*

*Nic.Dirkx@asml.com*

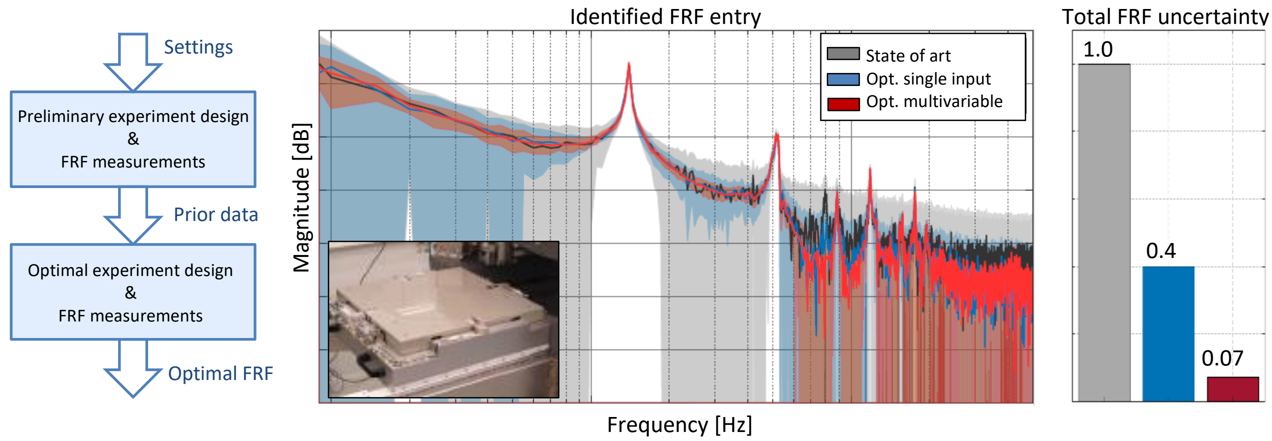
**Abstract for Poster**
The identification of Frequency Response Functions (FRFs) plays an essential role in control system design and diagnostics. To meet the ever-increasing machine requirements, there is a need to identify FRFs faster and more accurately. The quality of the FRF depends on the excitation signals used in the identification experiments, hence these must be designed carefully. Ideally, such design maximizes the excitation energy to achieve a good signal-to-noise ratio, while respecting the system limitations to guarantee safe operation. State of the art excitation methods in the industry address these items conservatively, since typically:

1) the spectrum is designed conservatively, e.g., uniform spectrum/ white noise,
2) system input and output constraints are addressed implicitly,
3) only a single input is excited at a time, also for MIMO systems.

Consequently, the FRF quality is non-optimal.

In this research, a systematic framework is developed to optimally design multisine excitations for the FRF identification of mechatronic systems [1]. Herein, items 1) and 2) are addressed through a 2-step design approach, see the left figure: in step 1, a preliminary experiment is performed to acquire prior system knowledge. In step 2, this data is used to synthesize customized excitation signals that maximize the FRF quality, while remaining within the system constraints. Additionally, for MIMO systems, item 3) is addressed through full multivariable excitation design that exploits the plurality of the actuator inputs [2].

The techniques are applied to a 7 x 8 wafer stage and compared to the industrial state of art (uniform spectrum). The resulting FRFs and their total uncertainty are shown in the middle and right figure, respectively. The optimized single input design (blue) outperforms the state of art (grey) by a factor 2.5, while the optimal multivariable excitations (red) achieve an improvement factor of 14.2. This demonstrates the power of the developed techniques.




*Left:* Two-step excitation design approach. *Middle:* Wafer stage setup and identified FRFs including 95% uncertainty region (shades). *Right:* Total uncertainty in FRFs. Optimized single input excitations (blue) outperforms the state of art *(grey),* while optimal multivariable excitations (red) achieve significantly highest quality.

**References**

[1] Dirkx N, van de Wijdeven J, Oomen T. Optimal experiment design for multivariable motion systems: with application to a next-generation wafer stage. In Proc. of 8th IFAC Symposium on Mechatronic Systems. 2019.

[2] Dirkx N, Oomen T. Multivariable Experiment Design with Application to a Wafer Stage: a Sequential Relaxation Approach for Dealing with Element-Wise Constraints. Submitted. 2019.

Keywords of the content are:
Optimal Experiment Design, system Identification, FRF measurements, multivariable systems, multisines