Comparison Between Control-Based Continuation and Phase-Locked Loop Methods for the Identification of Backbone Curves and Nonlinear Frequency Responses

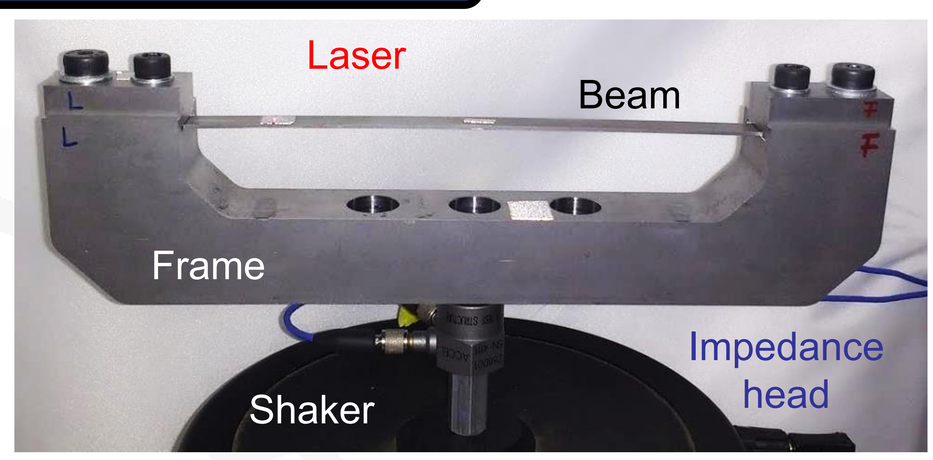
F. Müller, G. Abeloos, E. Ferhatoglu, M. Scheel, M. Brake, P. Tiso, L. Renson, M. Krack

Motivation

- Model-less experimental characterization of nonlinear structures with PLL and CBC
  - Backbone Curves
  - Nonlinear Frequency Responses
- No direct comparison of the methods has been performed until now

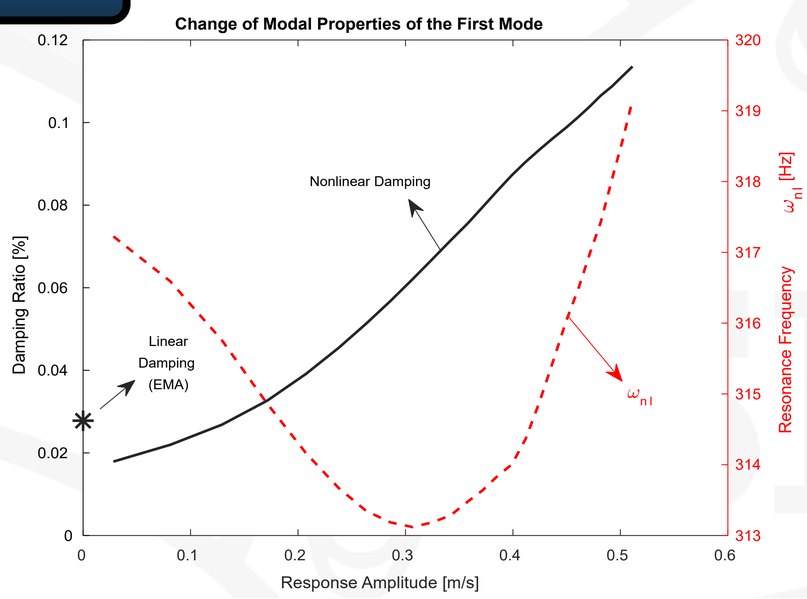
Experimental Setup

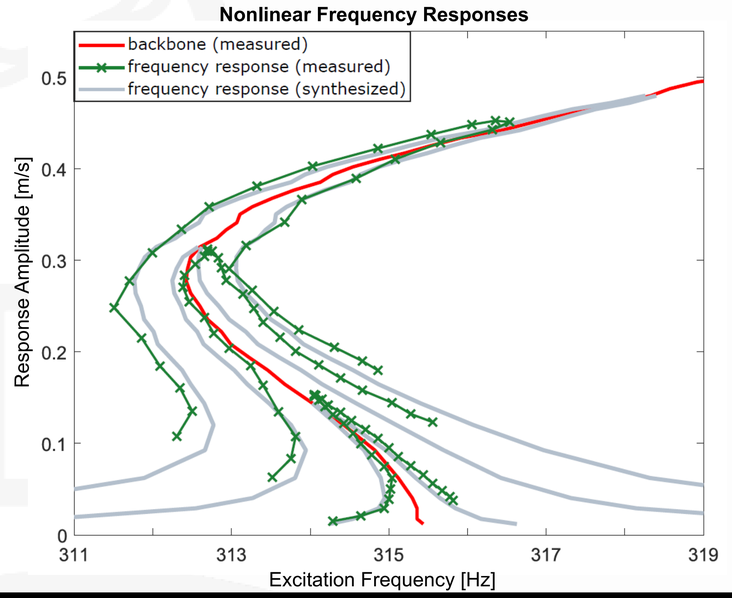
- Clamped-clamped curved beam
- Base excitation
- Velocity measured by laser
- Force measured by impedance head



Phase-Locked Loop (PLL)

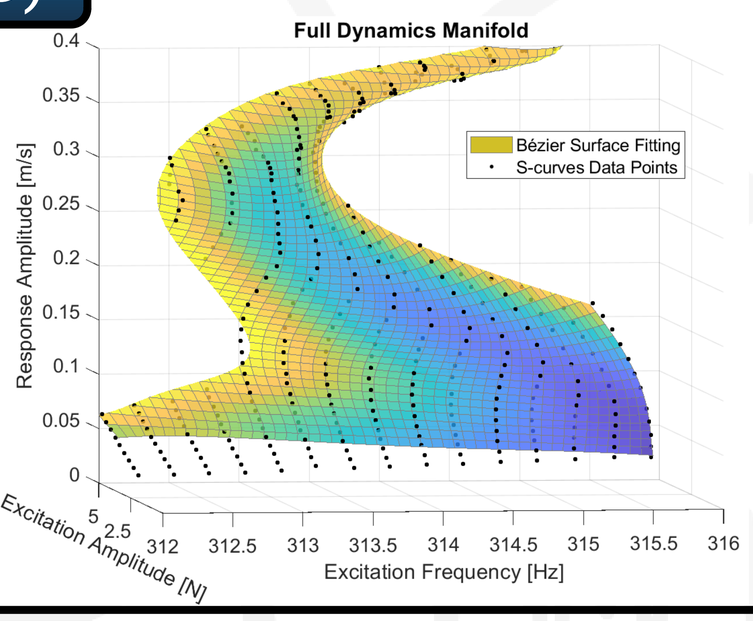
- Phaselag between excitation (=force) and response (=velocity) is evaluated online and controlled to a specific value
  - Stepping from low to high excitation amplitude at phaselag = 0°yields backbone curve
  - Stepping through phaselag at constant excitation amplitude yields frequency response including instable branches
- From the backbone measurement results:
  - amplitude dependent damping is calculated
  - frequency response is synthesized

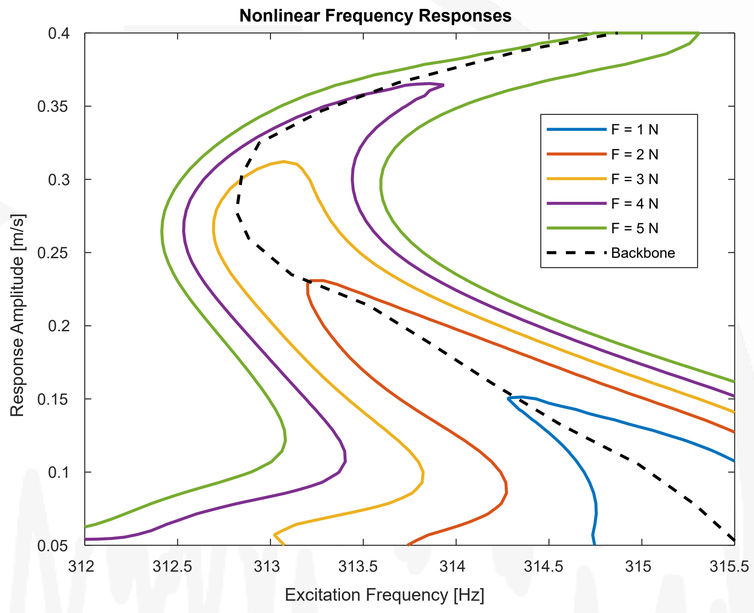




Control-Based Continuation (CBC)

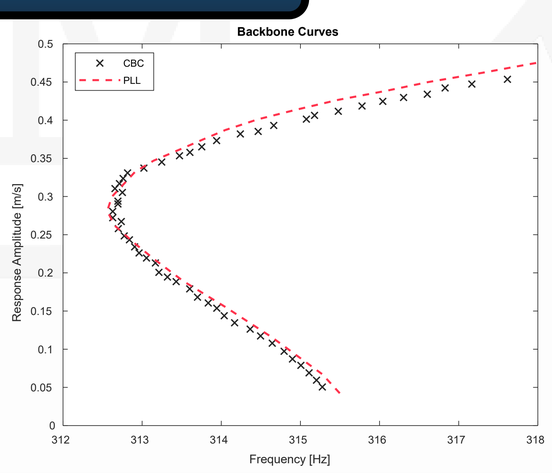
- Response amplitude is imposed by a PD controller
  - Control is made non-invasive by Picard iterations
  - Measured excitation force is made mono-harmonic by Newton iterations
- Backbone curves are obtained by increasing the response amplitude and tuning the excitation frequency until the quadrature of phase
- S-curves are obtained by increasing the response amplitude at constant excitation frequency
- The full dynamics manifold is constructed by minimizing the distance between a Bézier surface and S-curves data points





Conclusions

- Backbones obtained by both methods are consistent
- Nonlinear frequency response curves can be obtained by both methods
- Higher forcing harmonics can be cancelled with both methods
- Further studies could focus on:
  - comparison of performance
  - more complex nonlinearities



References

[1] Scheel, M., Peter, S., Leine, R. I., & Krack, M. (2018). A phase resonance approach for modal testing of structures with nonlinear dissipation. *Journal of Sound and Vibration*, *435*, 56-73.

[2] Peter, S., & Leine, R. I. (2017). Excitation power quantities in phase resonance testing of nonlinear systems with phase-locked-loop excitation. *Mechanical Systems and Signal Processing*, *96*, 139-158.

[3] Renson, L., Gonzalez-Buelga, A., Barton, D. A. W., & Neild, S. A. (2016). Robust identification of backbone curves using control-based continuation. *Journal of Sound and Vibration*, *367*, 145-158.

[4] Renson, L., Barton, D. A., & Neild, S. A. (2017). Experimental tracking of limit-point bifurcations and backbone curves using control-based continuation. *International Journal of Bifurcation and Chaos*, *27*(01), 1730002.

Universität Stuttgart · LIÈGE université · Politecnico di Torino · POLITECNICO DI TORINO · RICE · ETH zürich · University of BRISTOL

Tribomechadynamics Research Camp

Rice University, Houston TX
June 25th – August 2nd, 2019
http://tmd.rice.edu