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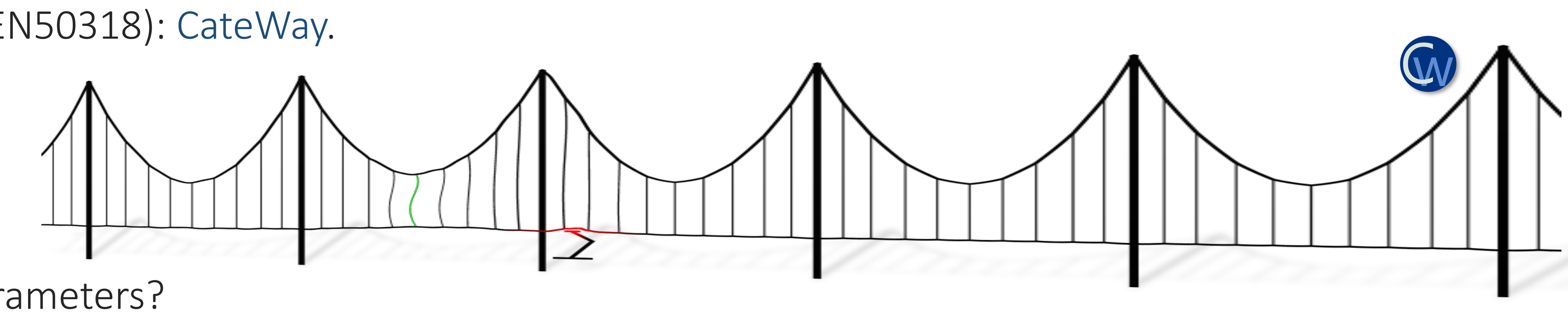
Dynamics of beam structures: From localized to distributed nonlinearities

Supervisor: Prof. Stefano Marchesiello
XXXII Cycle

Localized nonlinearity: dynamics of overhead contact lines

Modelling of overhead contact lines

- Certified nonlinear software (CEI EN50318): CateWay.
- Nonlinearity in:
  → Slackening of the droppers
  → Loss of contact



- How to properly tune the FEM parameters?
  → Comparison between FE models and a distributed parameter model.

S. Sorrentino, D. Anastasio, A. Fasana, S. Marchesiello, *Distributed parameters and finite element models for wave propagation in railway contact lines*, J. Sound Vib. 410 (2017) 1-18.

- How to define the damping distribution?
  → Study on non-proportional damping distributions: contact wire with a lumped damper.
  → Experimental measurements on railway contact wire and comparison with model predictions.

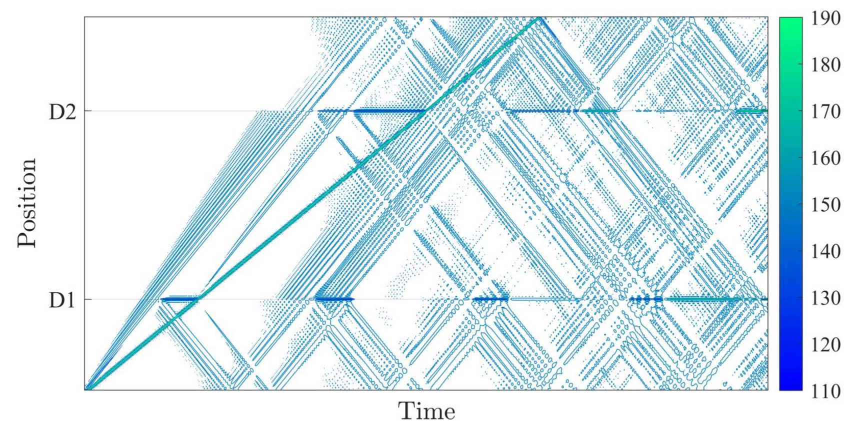
D. Anastasio, A. Fasana, L. Garibaldi, S. Marchesiello, Analytical investigation of railway overhead contact wire dynamics and comparison with experimental results, Mech. Syst. Signal Process. 116 (2019) 277–292.

- How to improve the performance of OCLs?
  → Design of nonlinear damping systems for OCLs, based on a negative stiffness absorber.

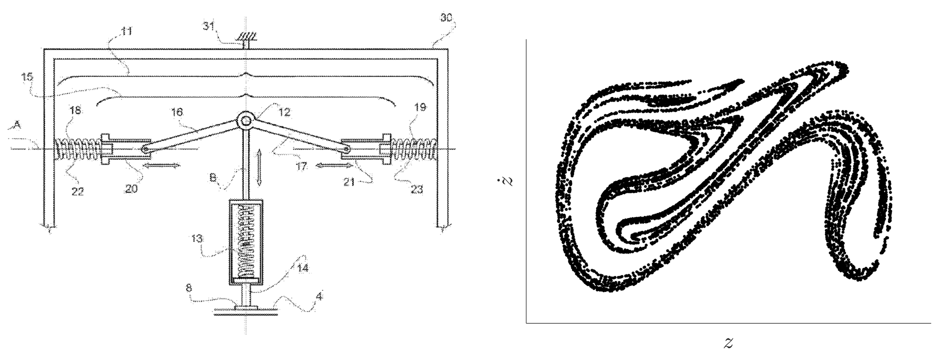
S. Marchesiello, D. Anastasio, L. Garibaldi, A. Fasana, International patent No. WO2018020397A8 (2018).

Photos of the experimental setup

Stress level (MPa) in the contact wire



Damper for OCLs and Poincaré map of the frame



Distributed nonlinearity: beam under large oscillations

Reduced Order Model (ROM)

- Constitutive nonlinear equation:

$$\mu\frac{\partial^2 y}{\partial t^2}+EI\frac{\partial^4 y}{\partial x^4}-\frac{EA}{2L}\left(\int_0^L\left(\frac{\partial y}{\partial x}\right)^2 dx\right)\frac{\partial^2 y}{\partial x^2}=f(x,t)$$

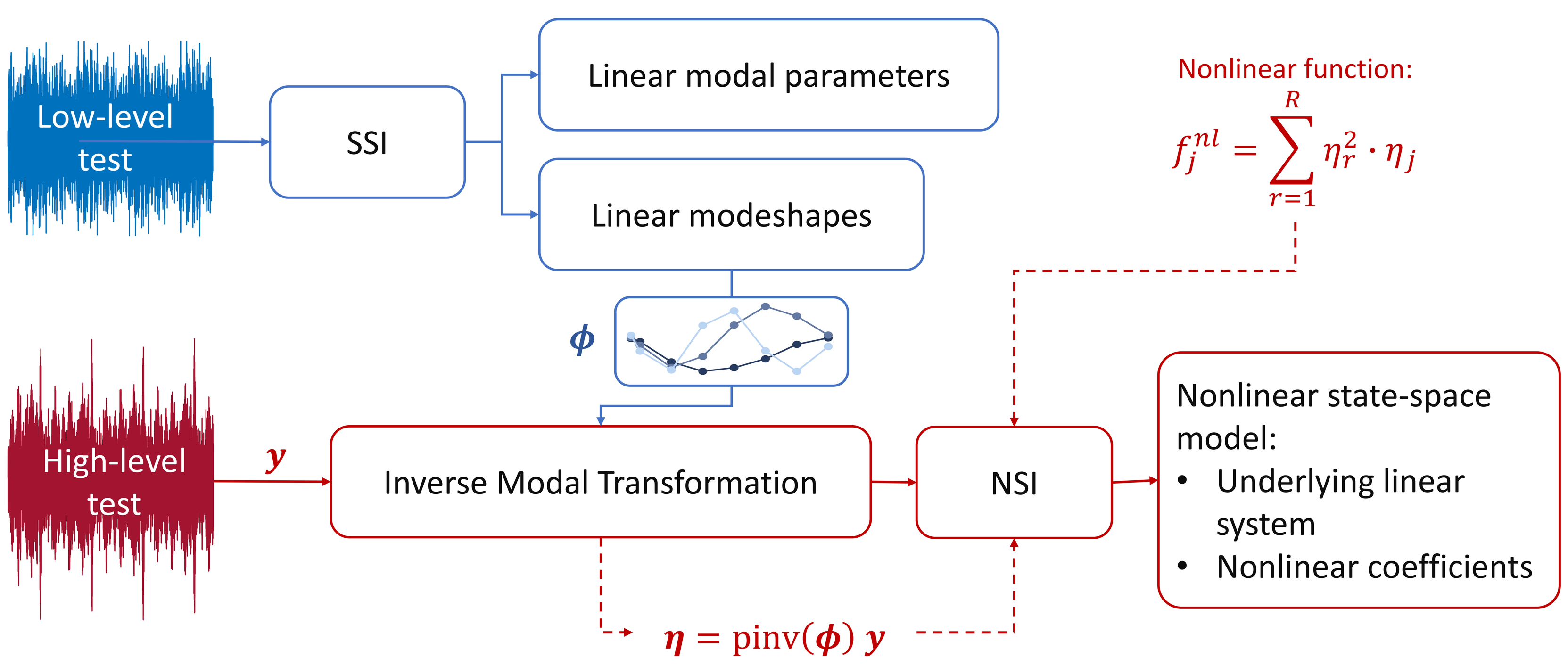
- A ROM is built starting from the linear modeshapes $\boldsymbol{\phi}_j$
- A set of N nonlinear equations in the modal domain is obtained considering N modes:

$$m_j\ddot{\eta}_j+k_j\eta_j-\frac{EA}{2L}\sum_{r=1}^{R}\left(c_{1,r}^{nl}\eta_r^2\right)c_{2,j}^{nl}\eta_j=Q_j,\quad j=1,\dots,N,\quad R\le N$$

- The nonlinear term shows an odd nonlinearity coupling different modes.

Nonlinear System Identification

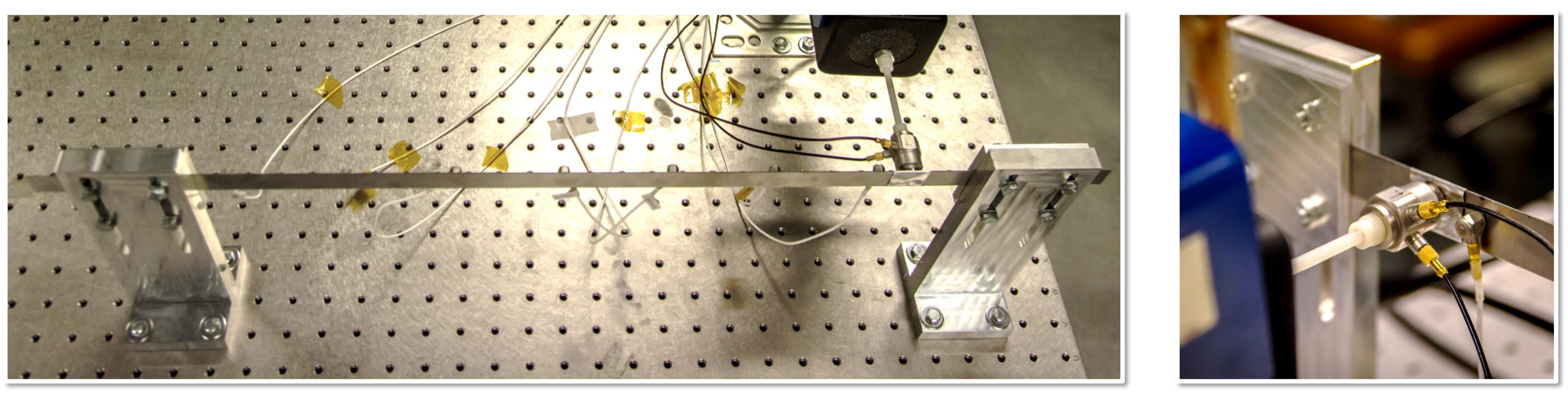
- NSI (Nonlinear Subspace Identification) method is be used to extract the modal parameters of the underlying linear system, and to identify the nonlinear coefficients.
- The identification is performed in the (extended) modal domain.



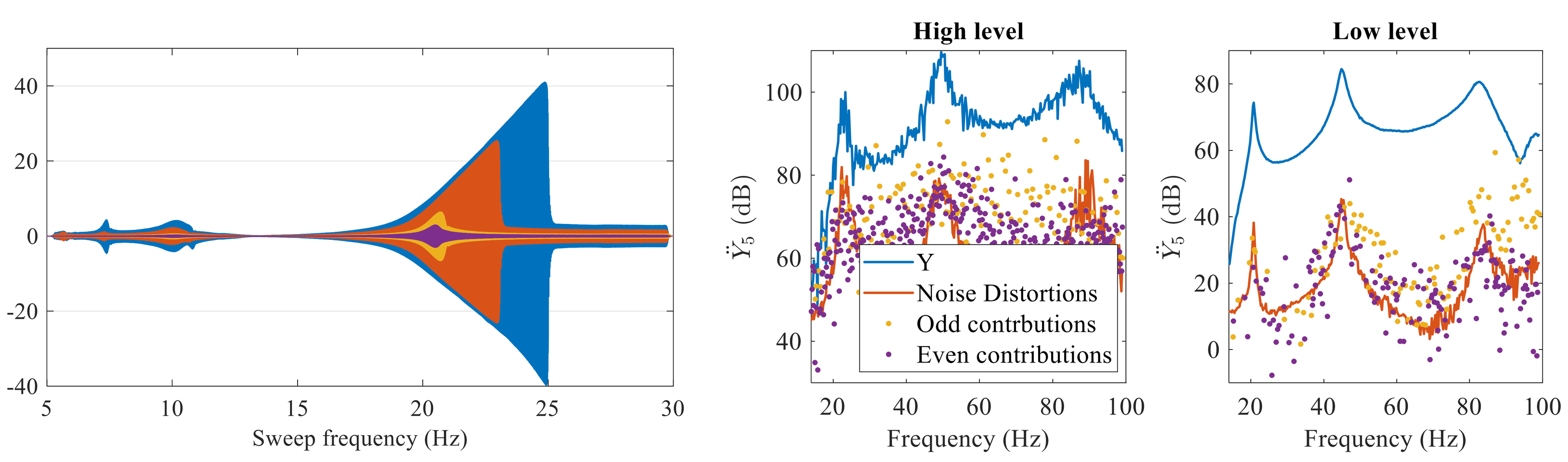
Experimental tests

- Tests are conducted at University of Liège, Space Structures and Systems Lab.
- A very thin alloy beam is driven through large oscillations, showing a distinctive distributed nonlinear behavior.
- NSI is applied to identify the nonlinearity.
- Even nonlinear contributions are included as well, to account for asymmetries in the structure.

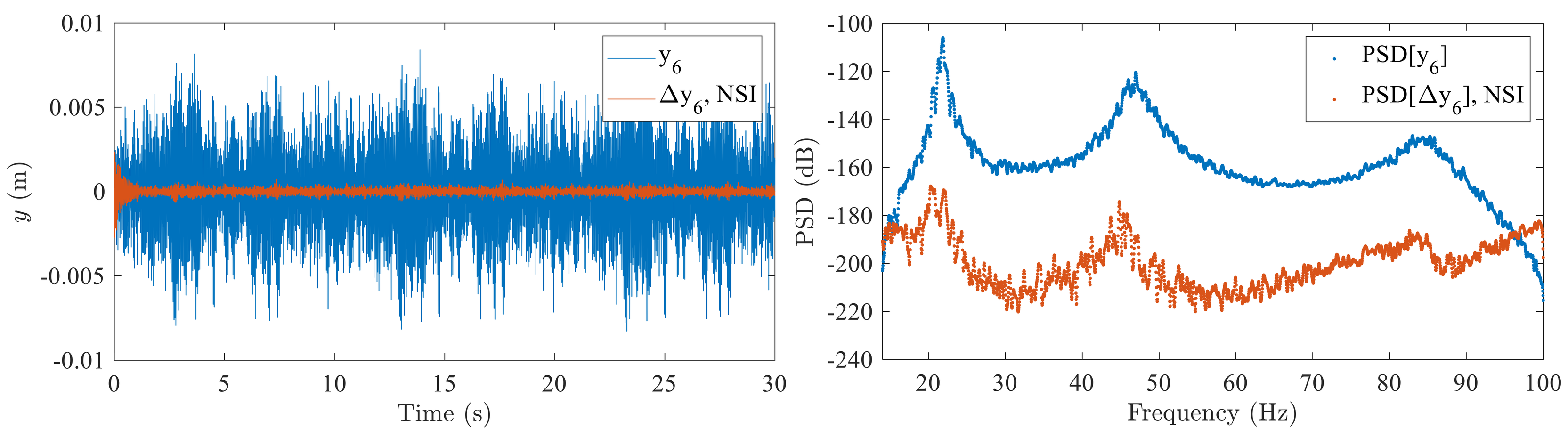
Photos of the experimental setup



Sweep tests and nonlinearity detection for different amplitudes: from linear to nonlinear



Results of the identification



D. Anastasio, S. Marchesiello, J.P. Noël, G. Kerschen, Subspace-Based Identification of a Distributed Nonlinearity in Time and Frequency Domains, Nonlinear Dynamics, Volume 1, Proceedings of IMAC XXXVI, Springer (2018) 283-285