FACULTY OF ENGINEERING
AND ARCHITECTURE

DYNAMICAL SYSTEMS AND CONTROL (DYSC) RESEARCH GROUP

EXPLOITING NONLINEARITY IN VIBRATION CONTROL DEVICES

dr. ir. Kevin Dekemele

GHENT UNIVERSITY

MŰEGYETEM 1782

Arts Sciences et Technologies et Métiers

Lodz University of Technology

ABOUT ME: CAREER GHENT

- MA Electromechanical engineer: control engineering (2015)

- Teaching assistent (2015-2021)
  - 40 % Teaching (Dynamical systems/Vibrations)
  - 60 % Research
  - Promotor: professor Mia Loccufier

- Post-doc (04/2021-…)
  - Short-time projects (until 11/2022) & National Fellowship (11/2022 --)

  - Research stay in Budapest (Hungary) (02/2022-04/2022)
  - Research stay ENSAM Lille (France) (02/2023-02/2024)

  - 2 PhD students + 3 Visiting from Southeast University /Tongji/ Lodz

GHENT UNIVERSITY

ABOUT ME: BELGIUM

Flanders (60% population, Dutch)

German (<1%)

Wallonia (40% population, French)

ABOUT ME: BELGIUM

Stoofvlees / Carbonade Flamand

Moule frites

Frietkot/

Baraque à frites

Belgian Beers

Matching beer glass (don’t mix)

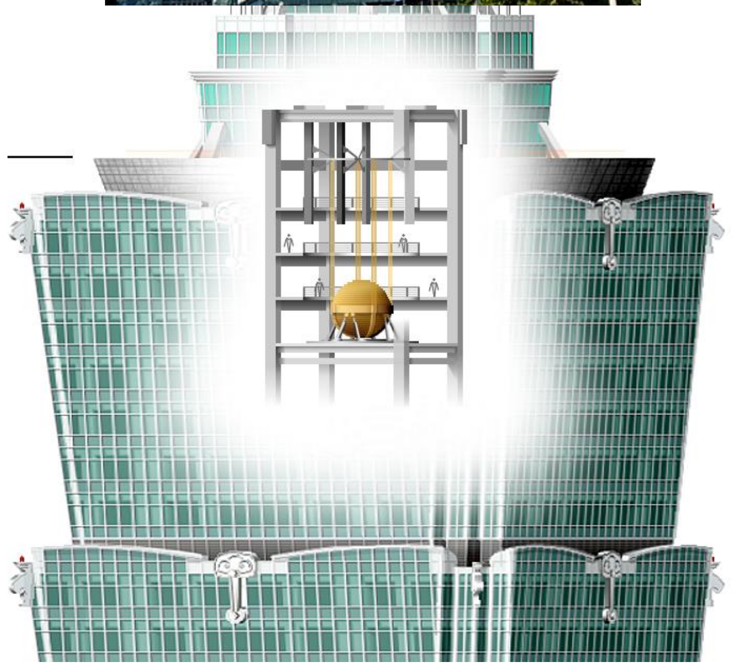
ABOUT ME: BELGIAN SWEETS

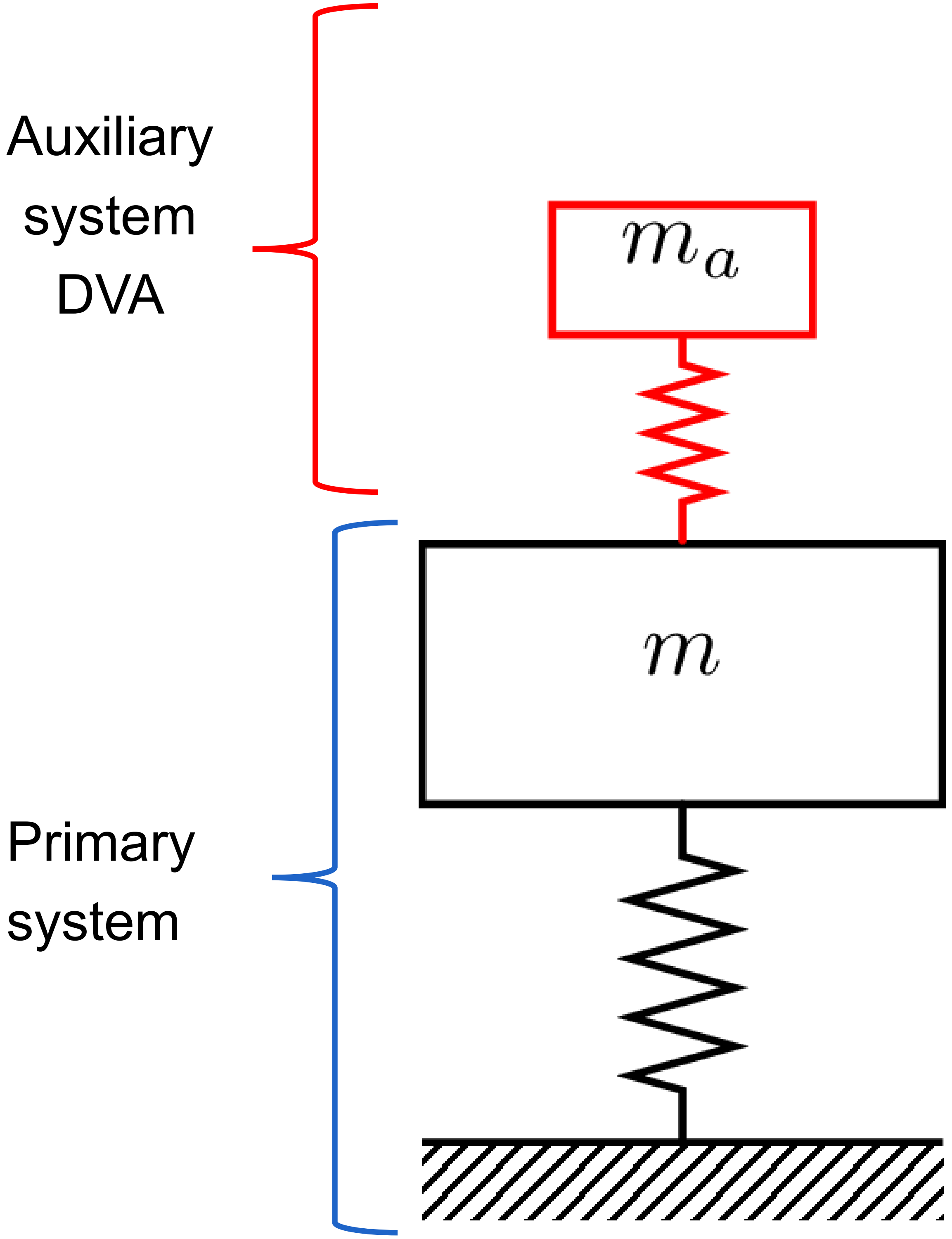
ABOUT ME: GHENT

RESEARCH: NONLINEAR ENERGY SINK

GHENT UNIVERSITY

DYNAMIC VIBRATION ABSORBER (DVA)





GHENT UNIVERSITY

ON-SITE VISITS

Millenium Bridge, London

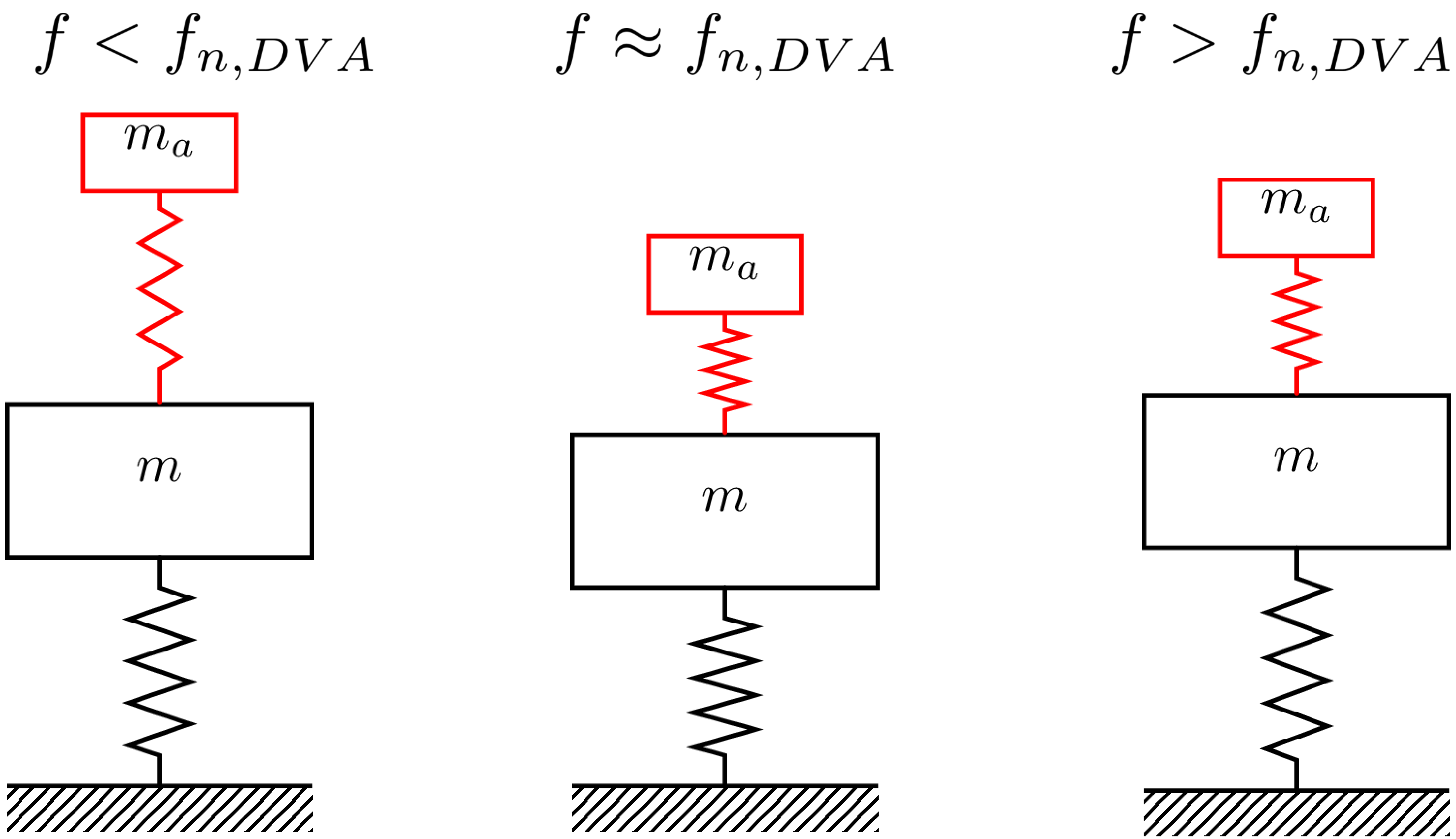
Shanghai Tower, Shanghai

PROBLEM CONVENTIONAL DVA

– Sensitive to only 1 frequency
    1. Shifting vibration frequency?
    2. Multiple vibration frequencies?

PROBLEM CONVENTIONAL DVA

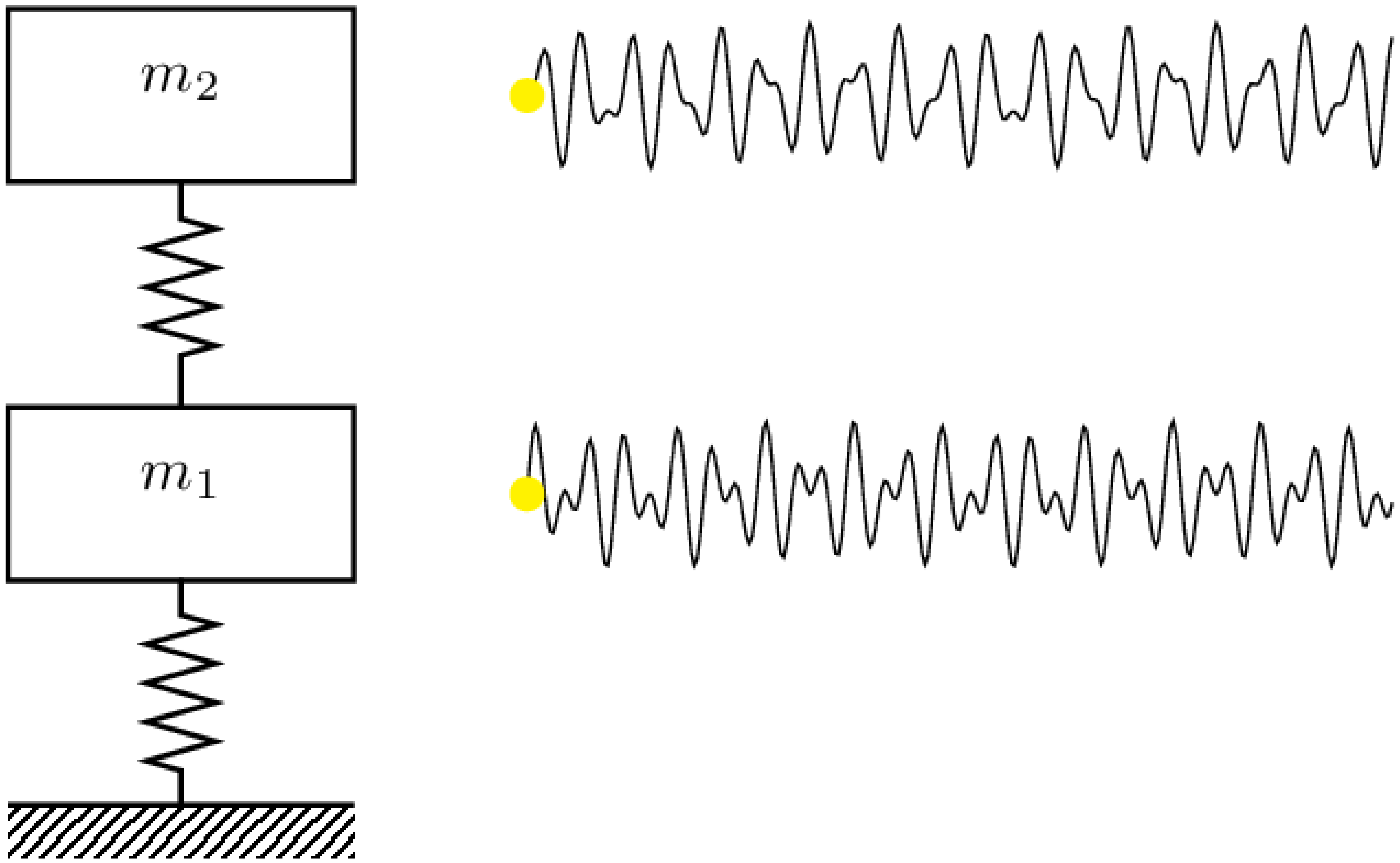
- Sensitive to only 1 frequency
  1. Shifting vibration frequency?
  2. Multiple vibration frequencies?



GHENT UNIVERSITY

PROBLEM CONVENTIONAL DVA

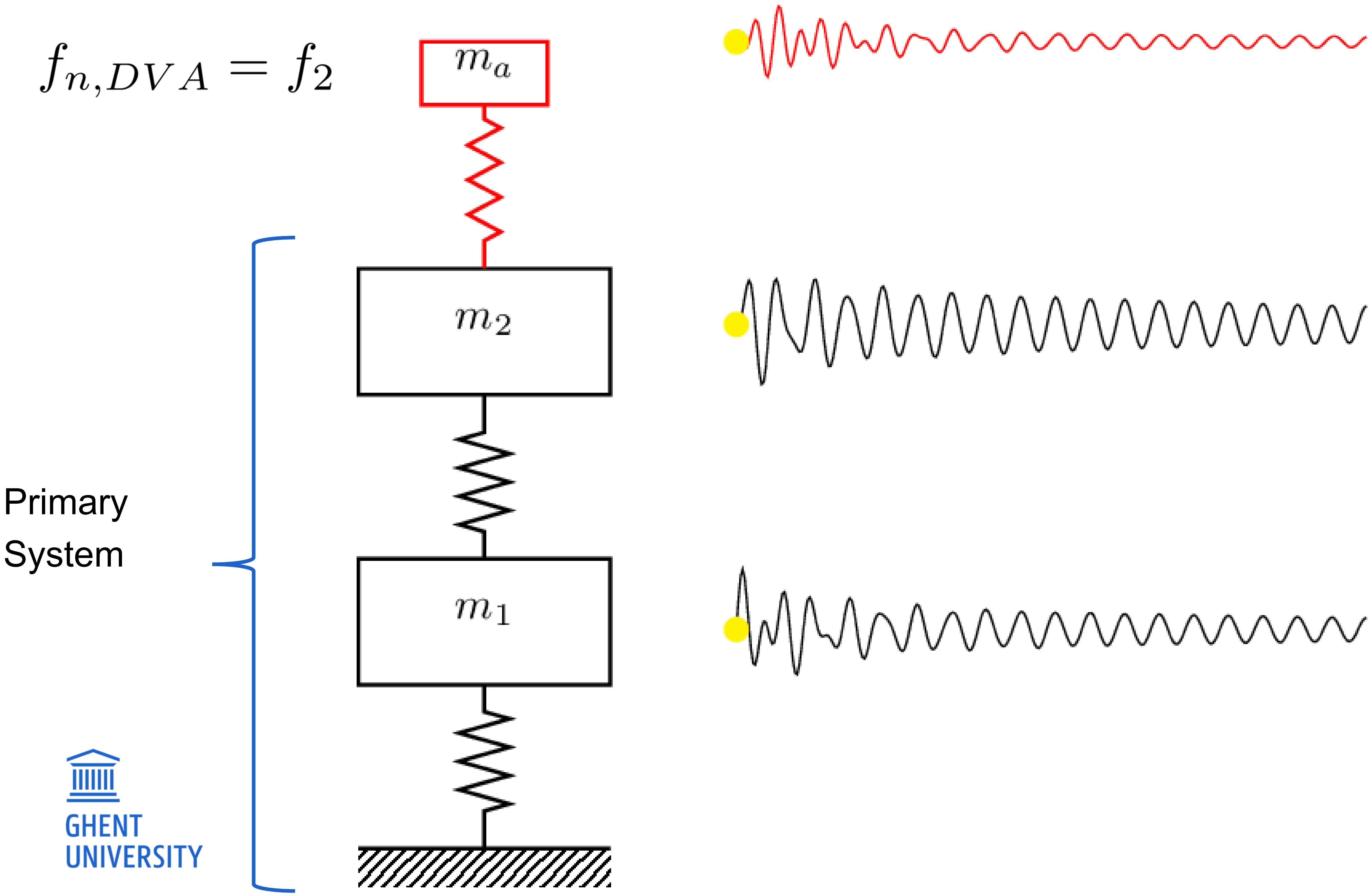
– Sensitive to only 1 frequency
  1. Shifting vibration frequency?
  2. Multiple vibration frequencies? $A_1 \sin(2\pi f_1 t + \phi_1) + A_2 \sin(2\pi f_2 t + \phi_2)$



GHENT UNIVERSITY

ADD LINEAR DYNAMIC VIBRATION ABSORBER

$$f_{n,DVA} = f_2$$

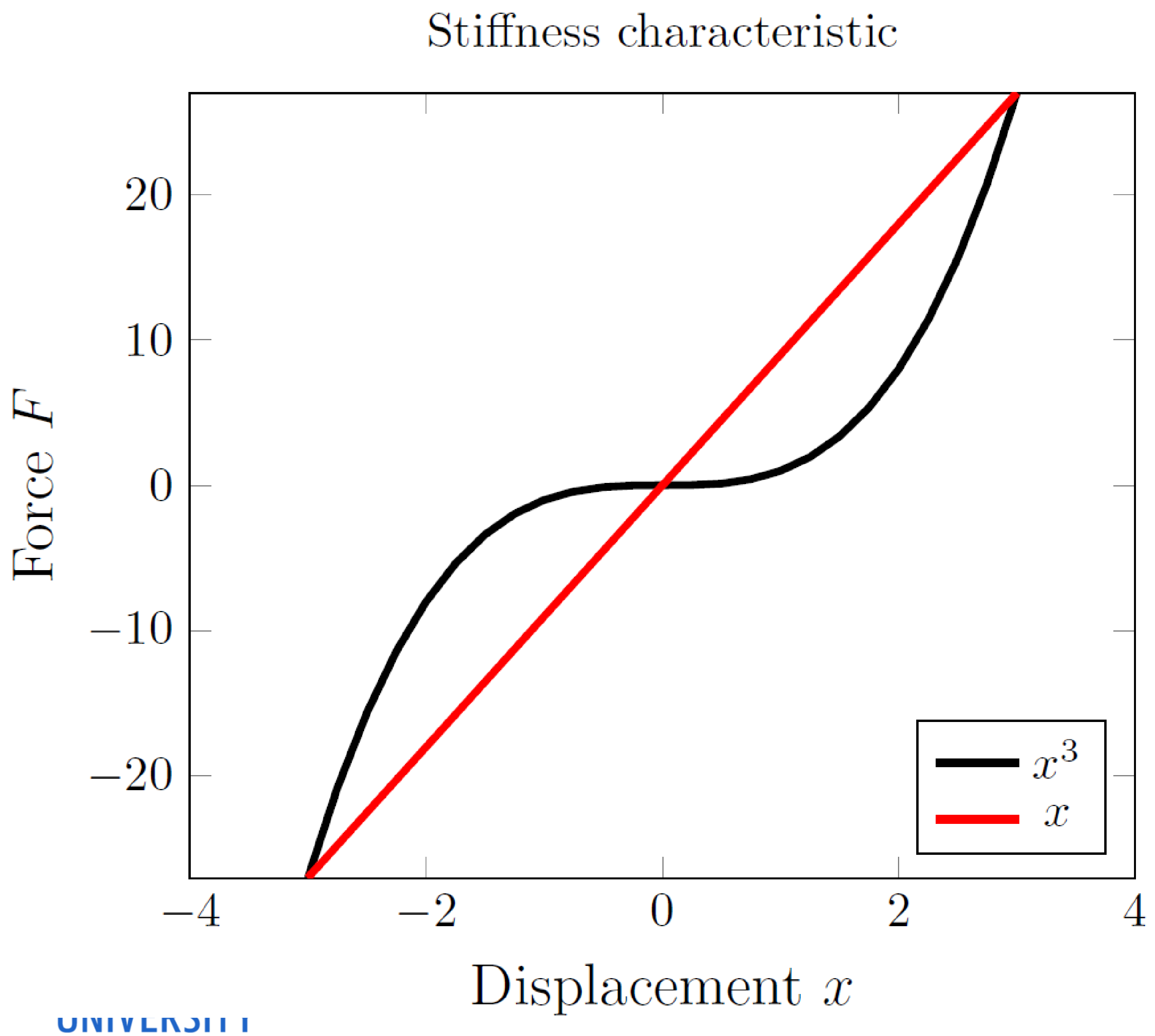


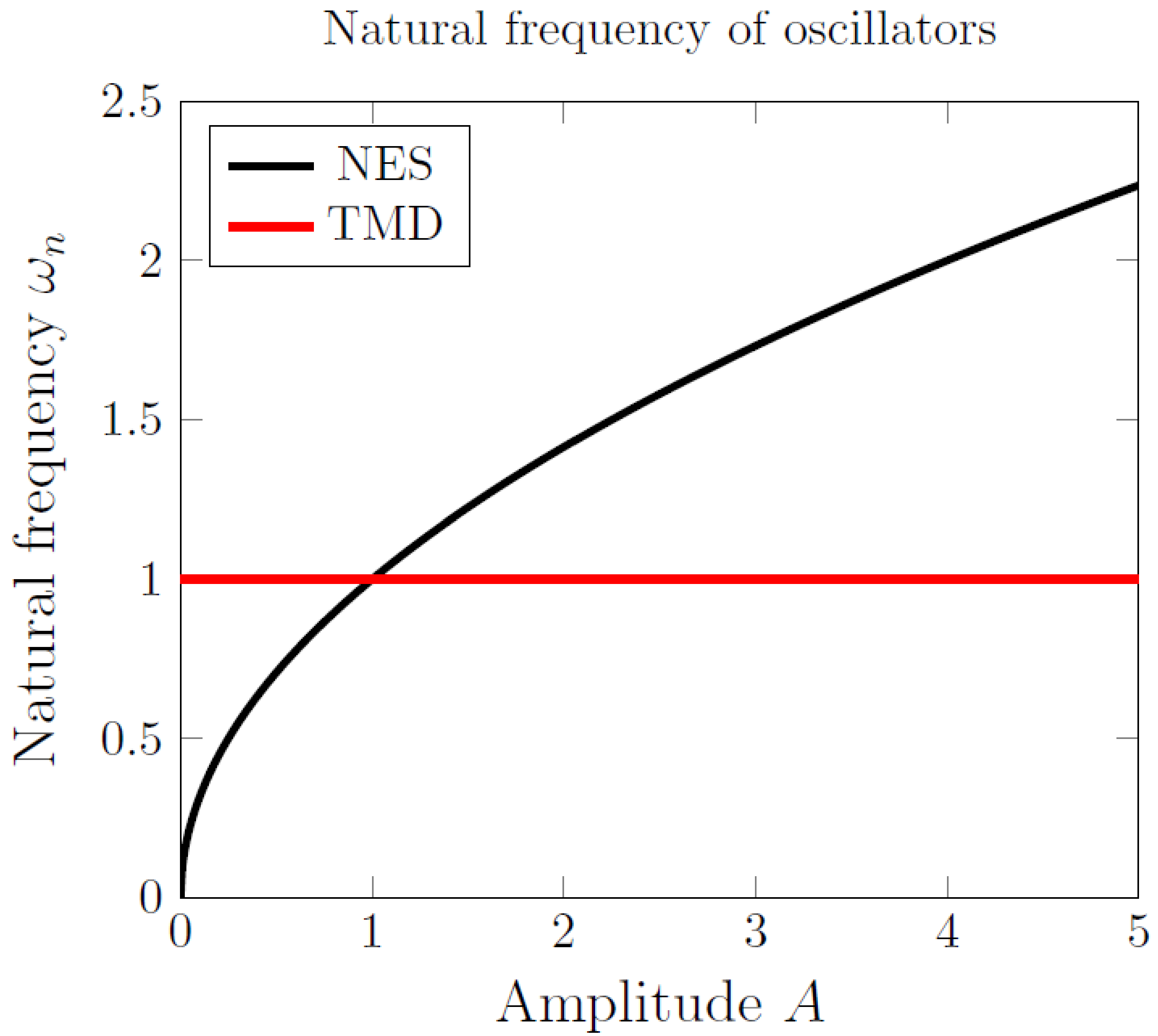
PROBLEM CONVENTIONAL DVA

- Reason: Hooke's law

$$f_{n,DVA} = \frac{1}{2\pi}\sqrt{\frac{k_a}{m_a}}$$

- Nonlinear DVA: Nonlinear energy sink





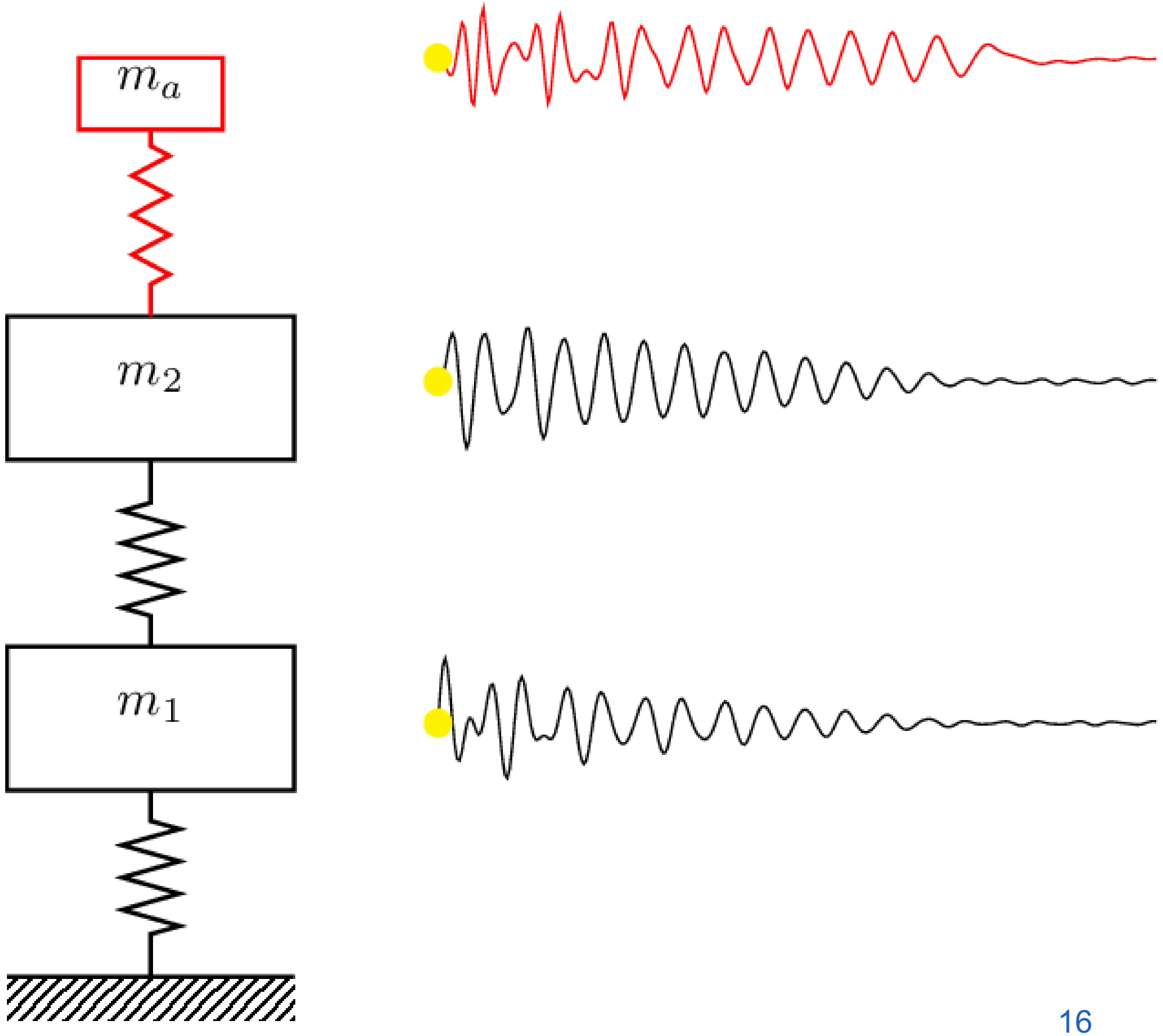
CONTENT

- **Resonance Capture Cascade (Transient Load)**
- Practical realization
- Harmonic load: Hardening
- Harmonic load: Softening
- Piezoelectrical NES

GHENT UNIVERSITY

NONLINEAR ENERGY SINK (NES)

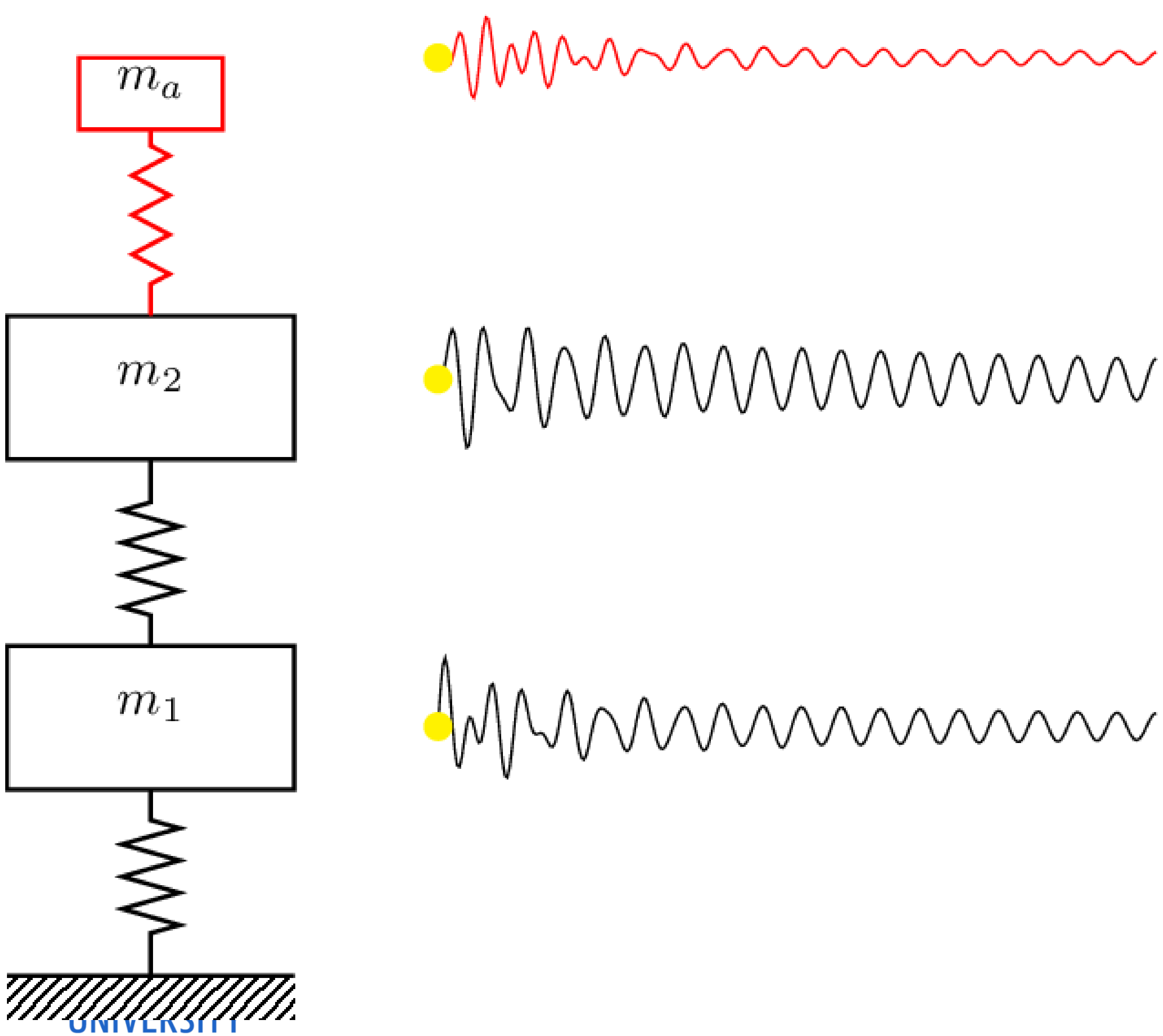
- Resonance capture cascade (RCC):
  - NES self-tunes to frequencies
  - Both frequencies damped



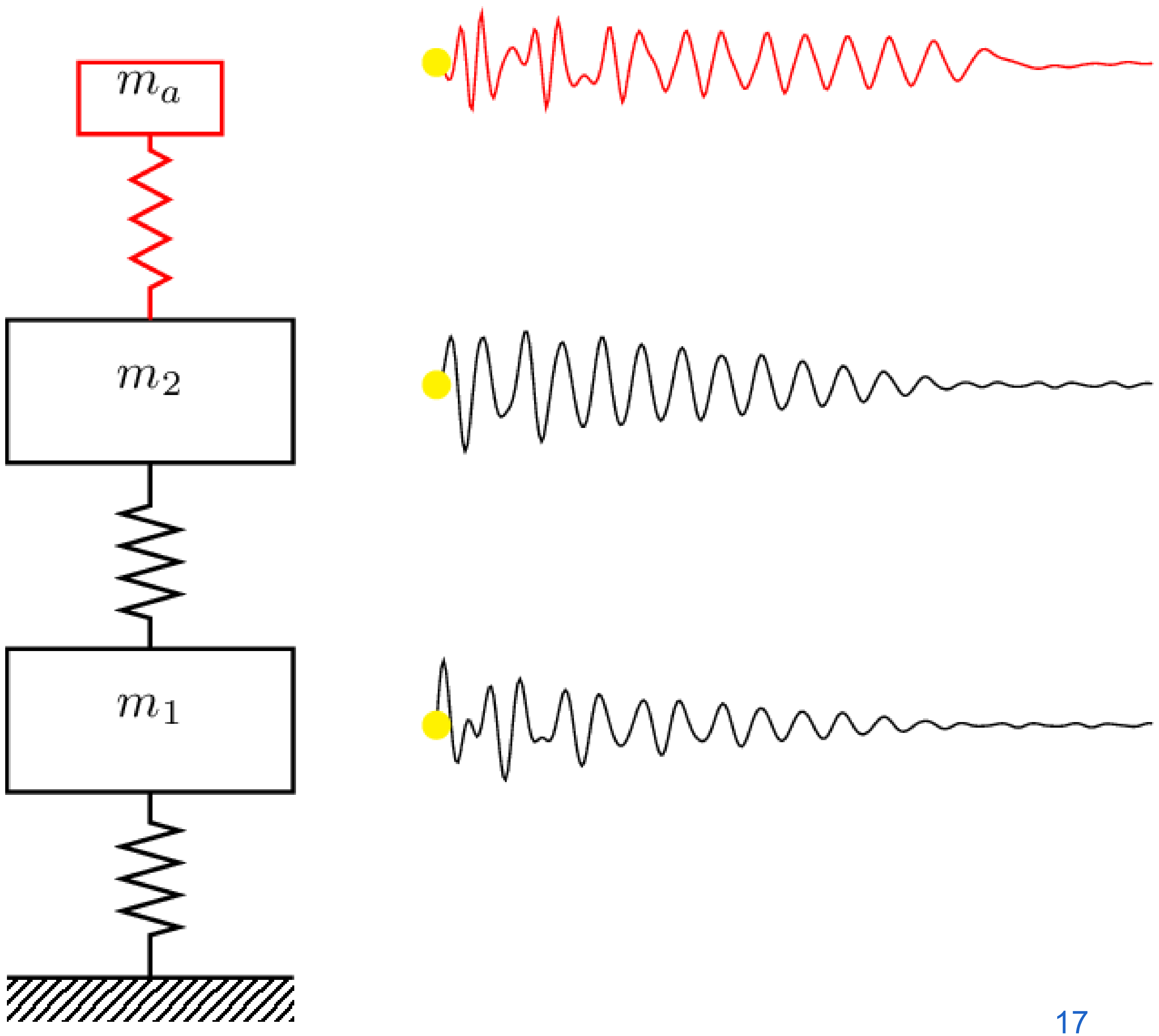
GHENT UNIVERSITY

NONLINEAR ENERGY SINK

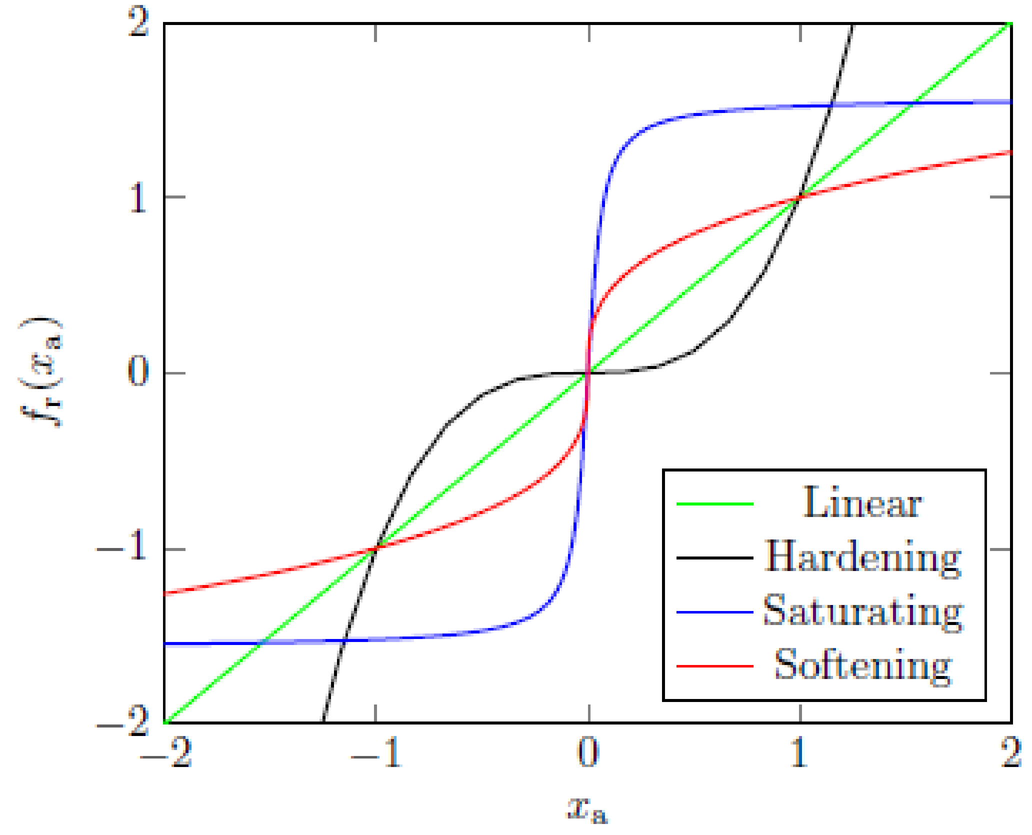
Conventional DVA



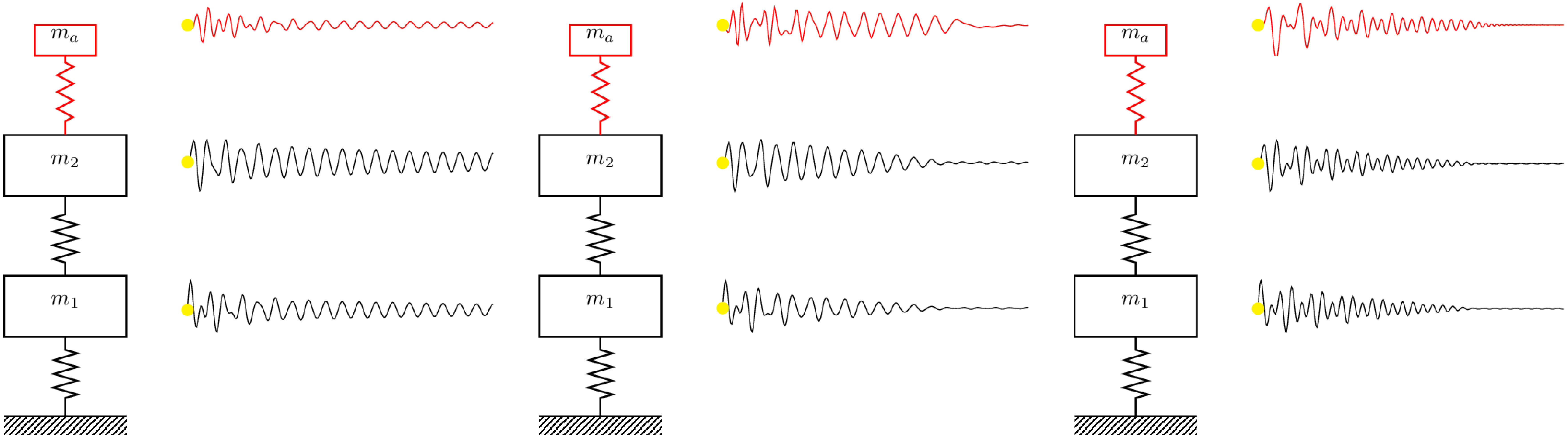
NES: RCC



SOFTENING SPRING

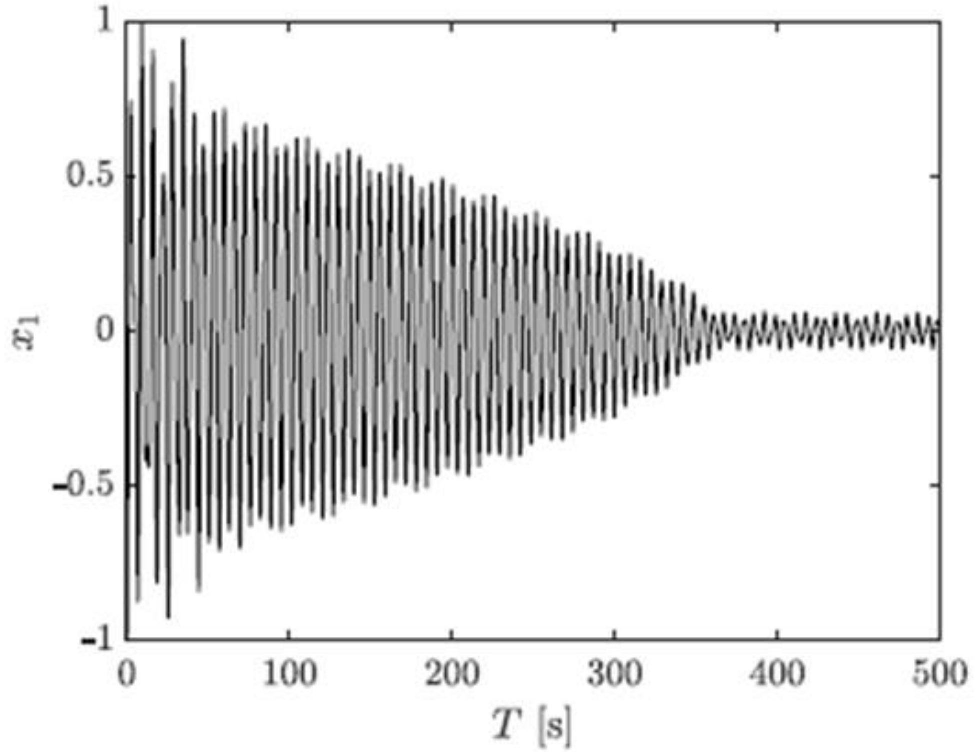


Softening Spring:
RCC from low to high
Frequency

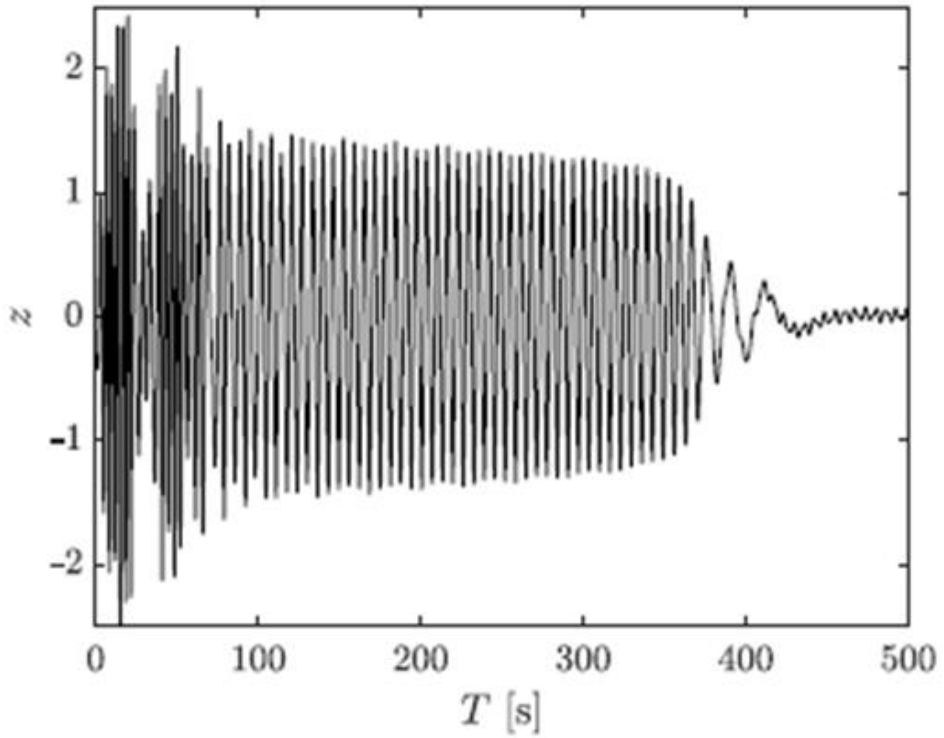


TIME SIMULATION HARDENING STIFFNESS

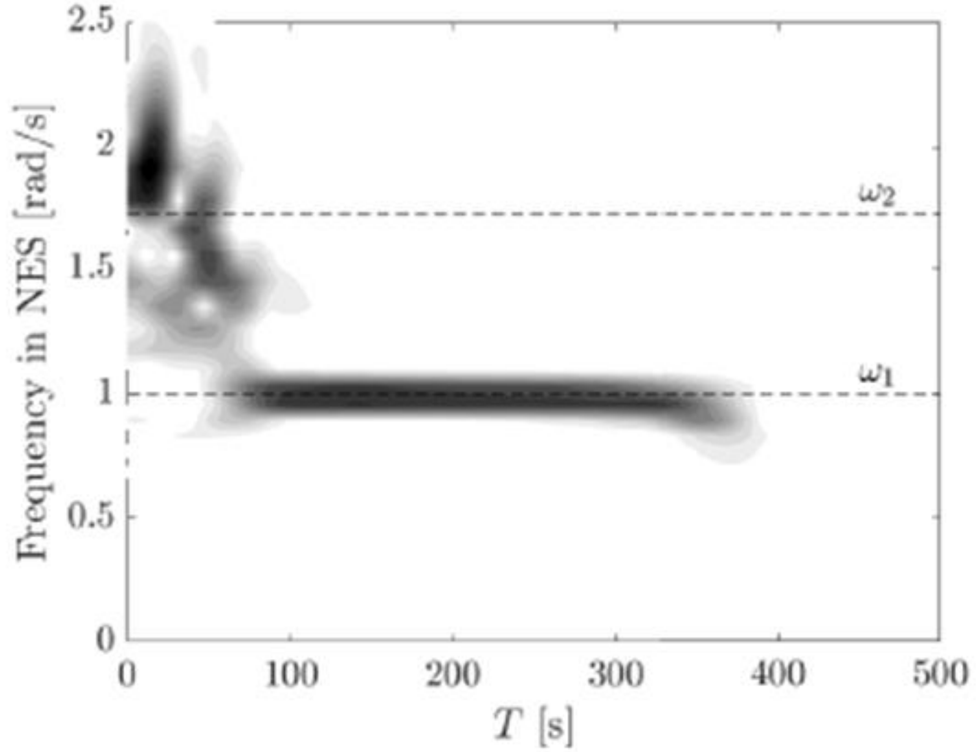
Physical vibrations x1

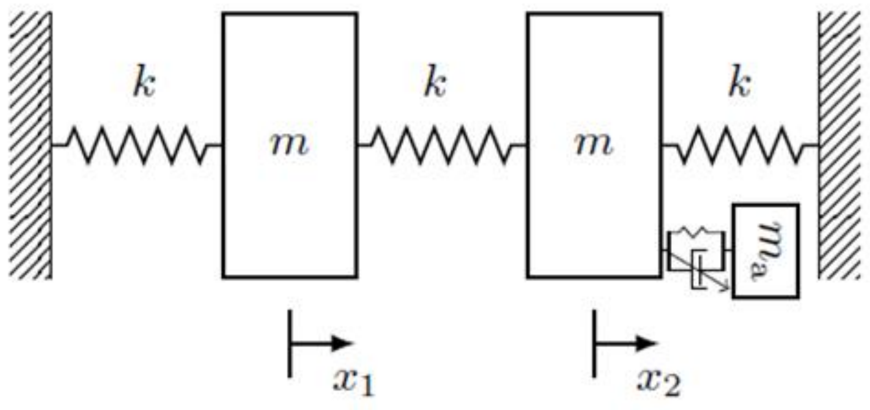


Relative absorber

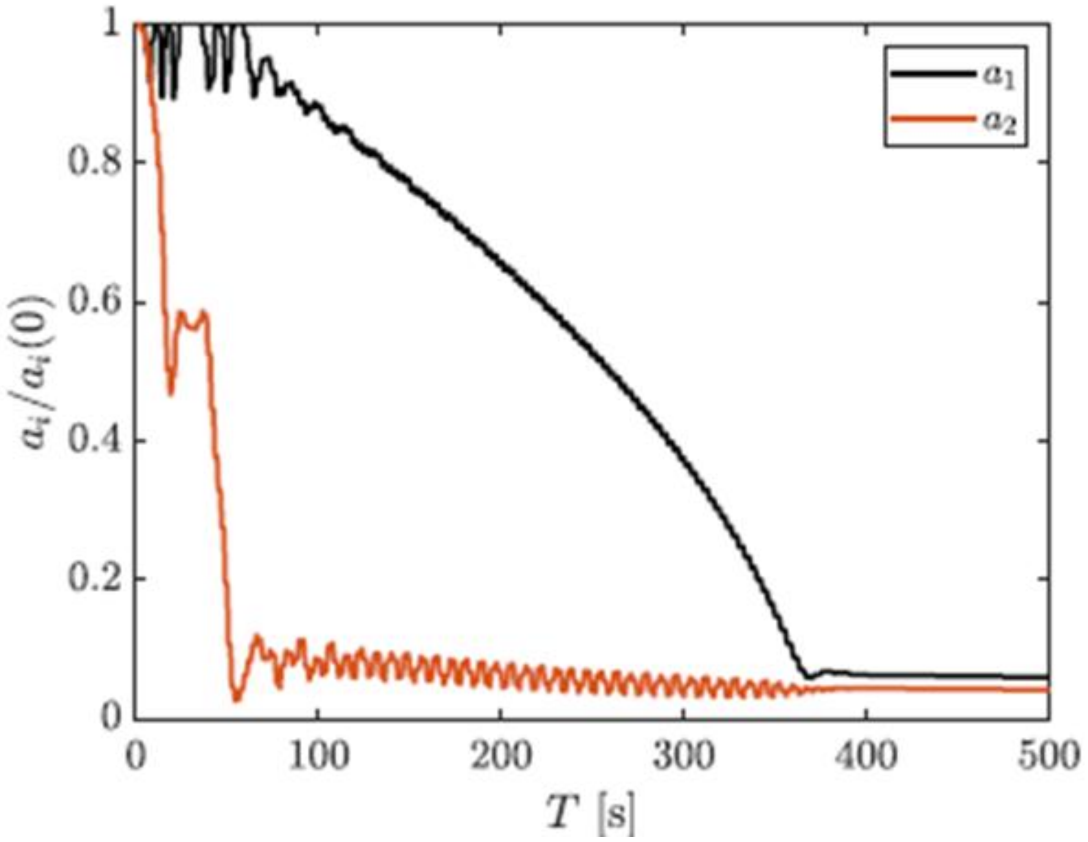


Wavelet absorber

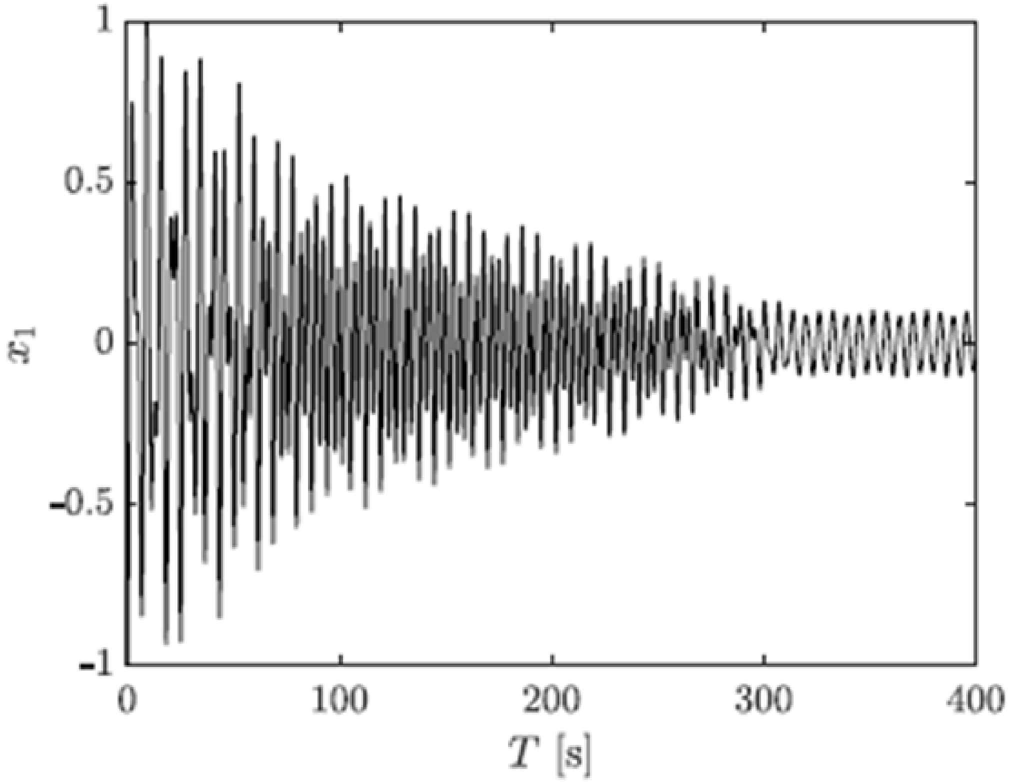


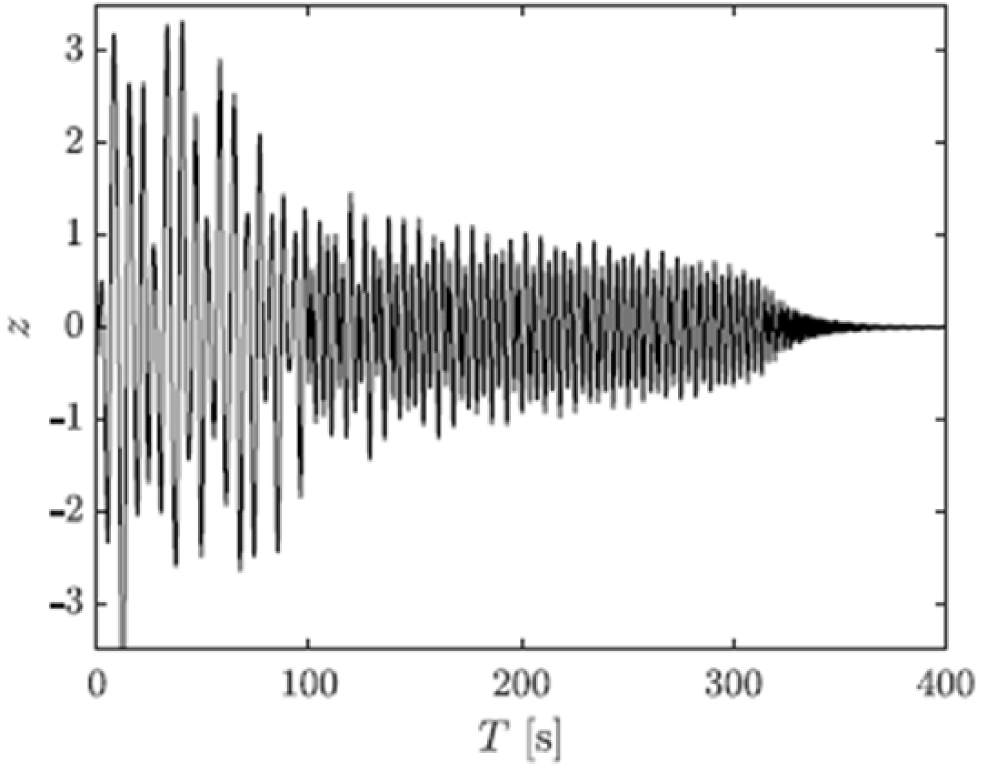


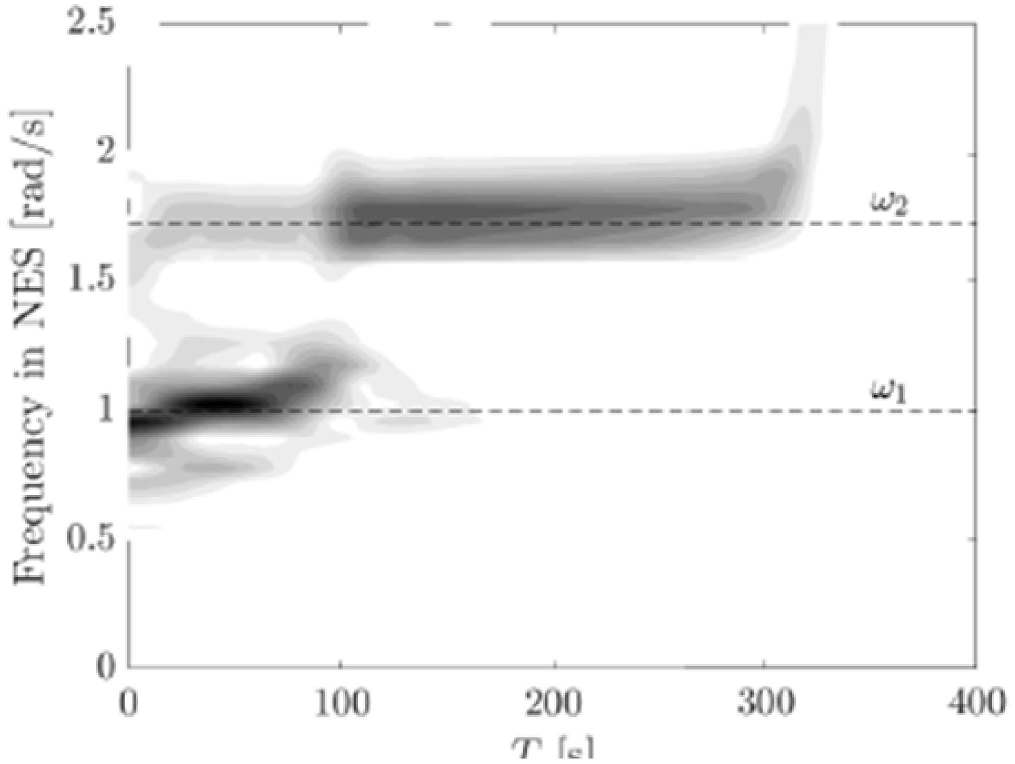
Modal vibrations



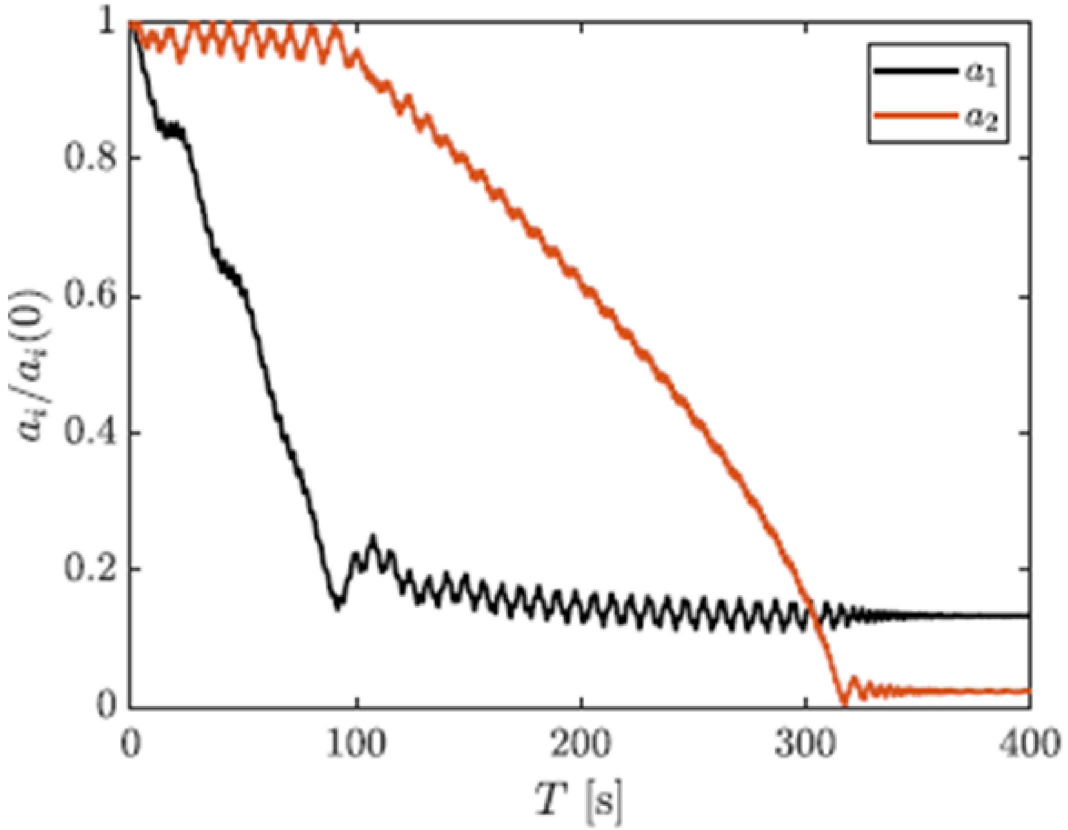
TIME SIMULATION SOFTENING STIFFNESS:







Modal vibrations



Dekemele, K., Habib, G. Inverted resonance capture cascade: modal interactions of a nonlinear energy sink with softening stiffness. Nonlinear Dyn ***111****, 9839–9861 (2023). https://doi.org/10.1007/s11071-023-08423-9*

GHENT UNIVERSITY

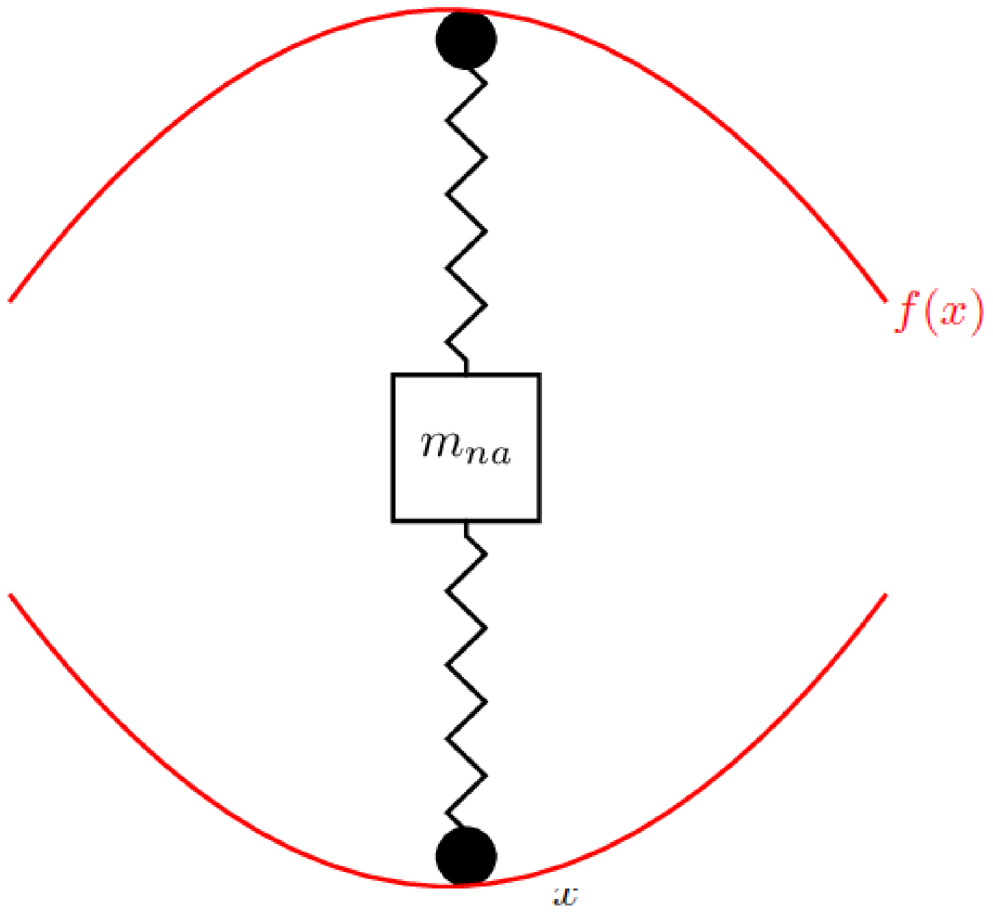
MŰEGYETEM 1782

CONTENT

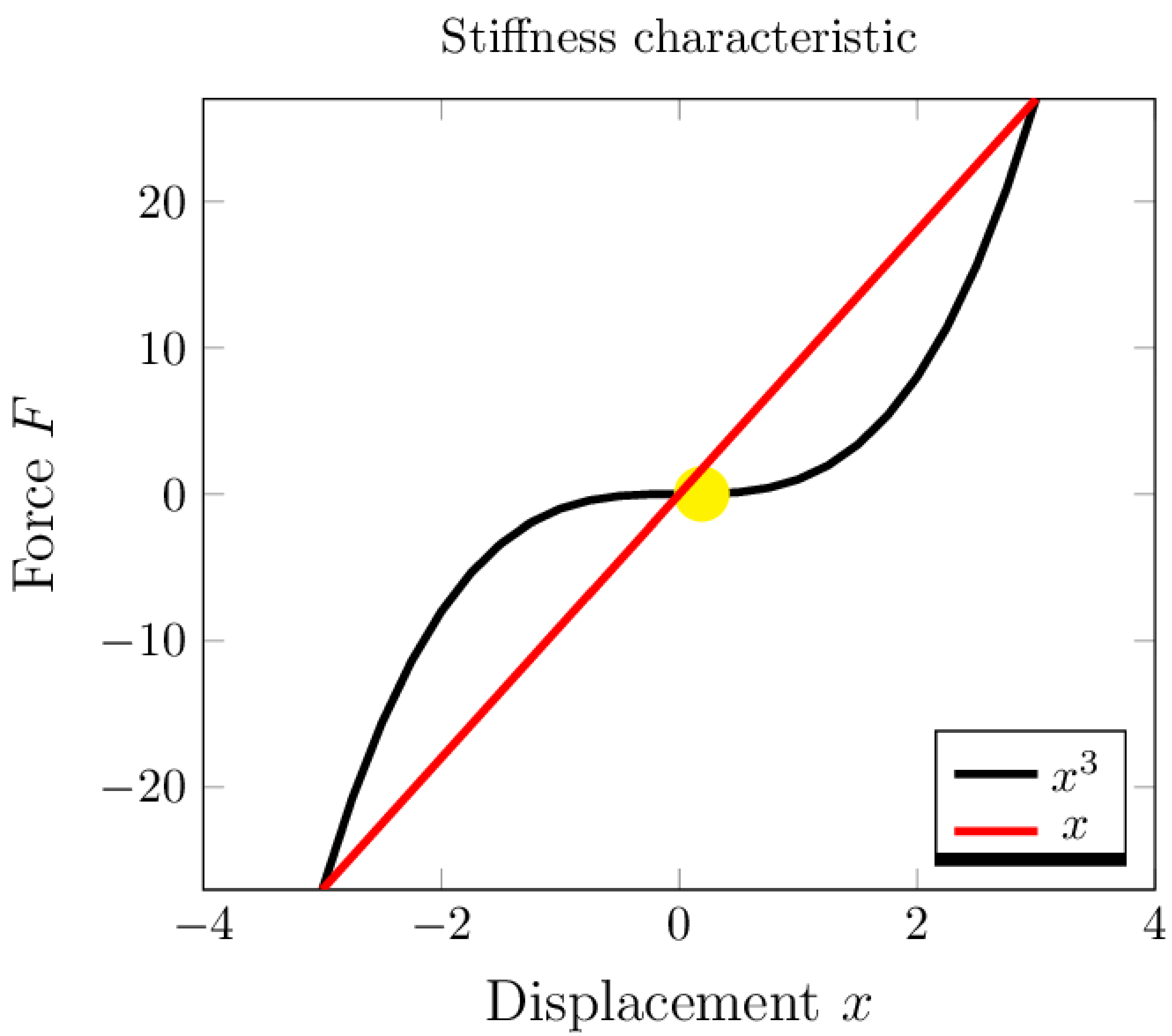
- Resonance Capture Cascade (Transient Load)
- **Practical realization**
- Harmonic load: Hardening
- Harmonic load: Softening
- Piezoelectrical NES

NES REALIZATION: GHENT UNIVERSITY

Mechanism

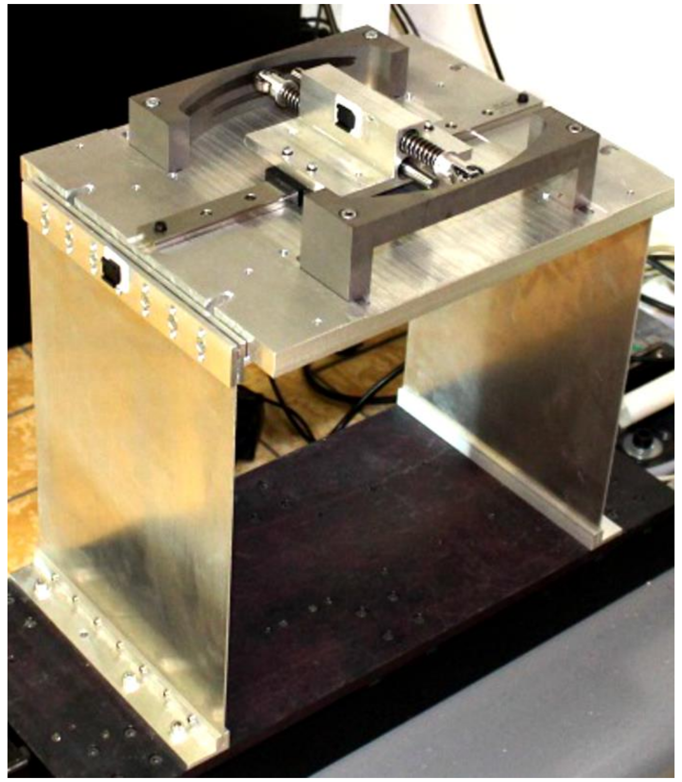


Result



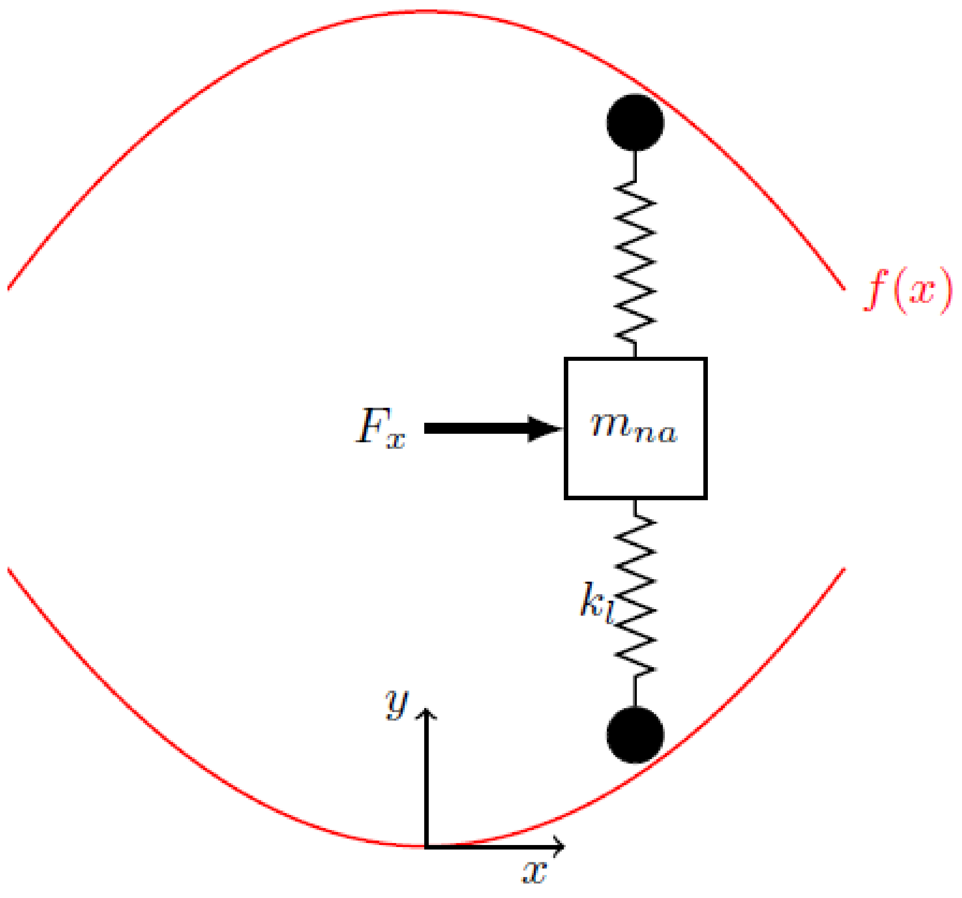
NES REALIZATION

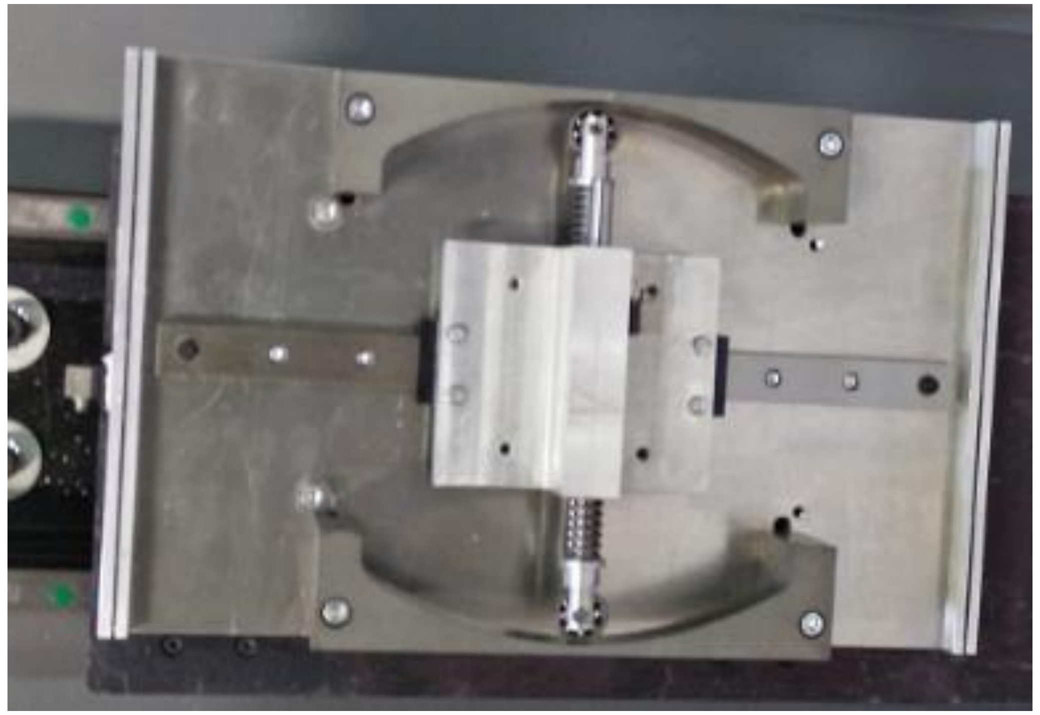
Implementation

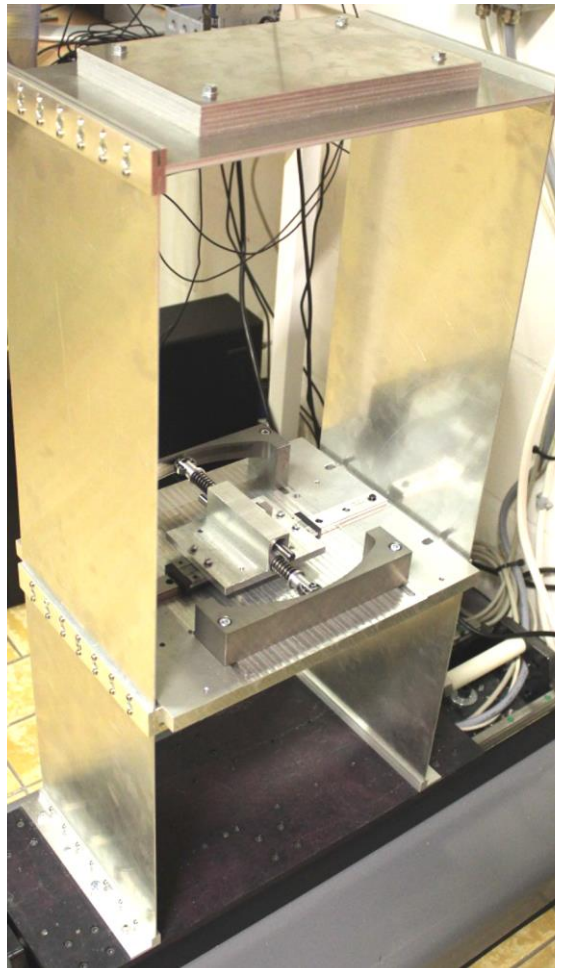


Mechanism

Realization

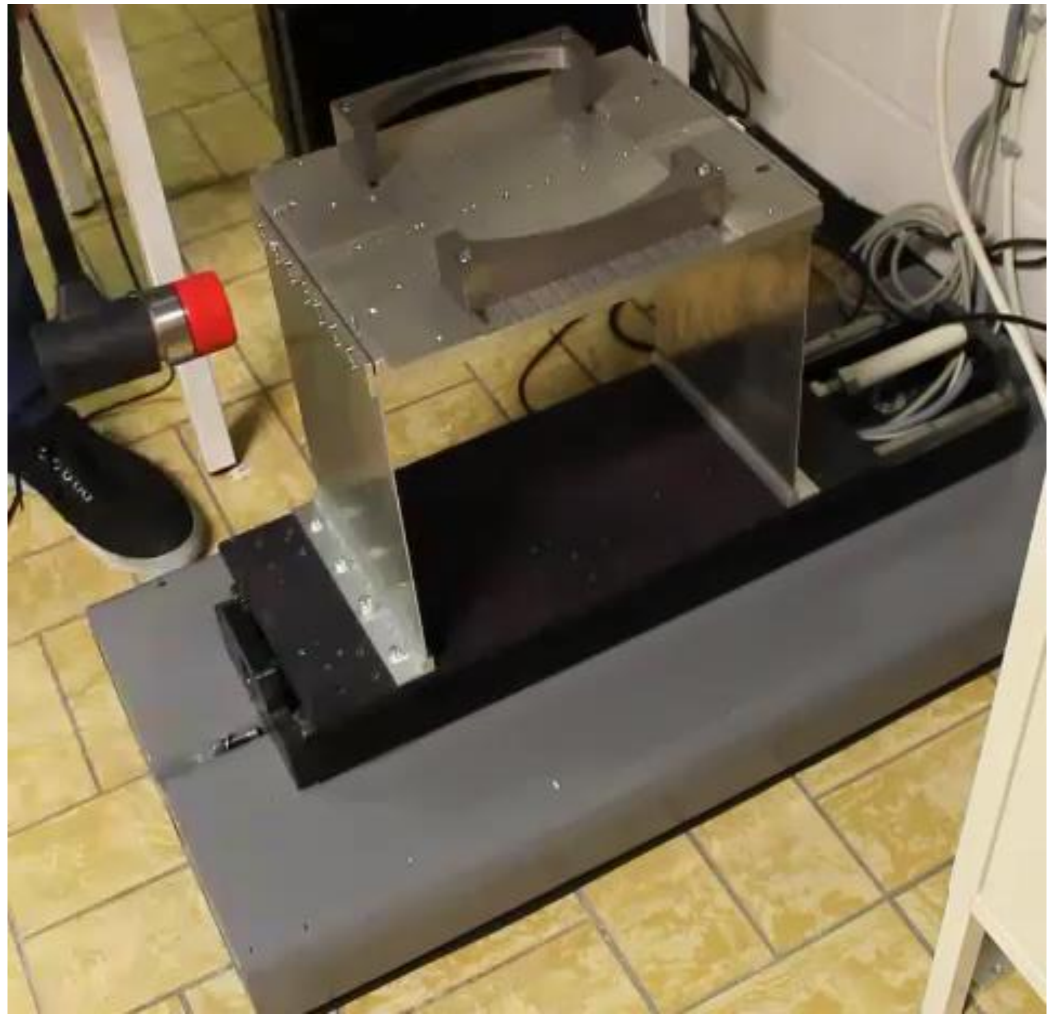




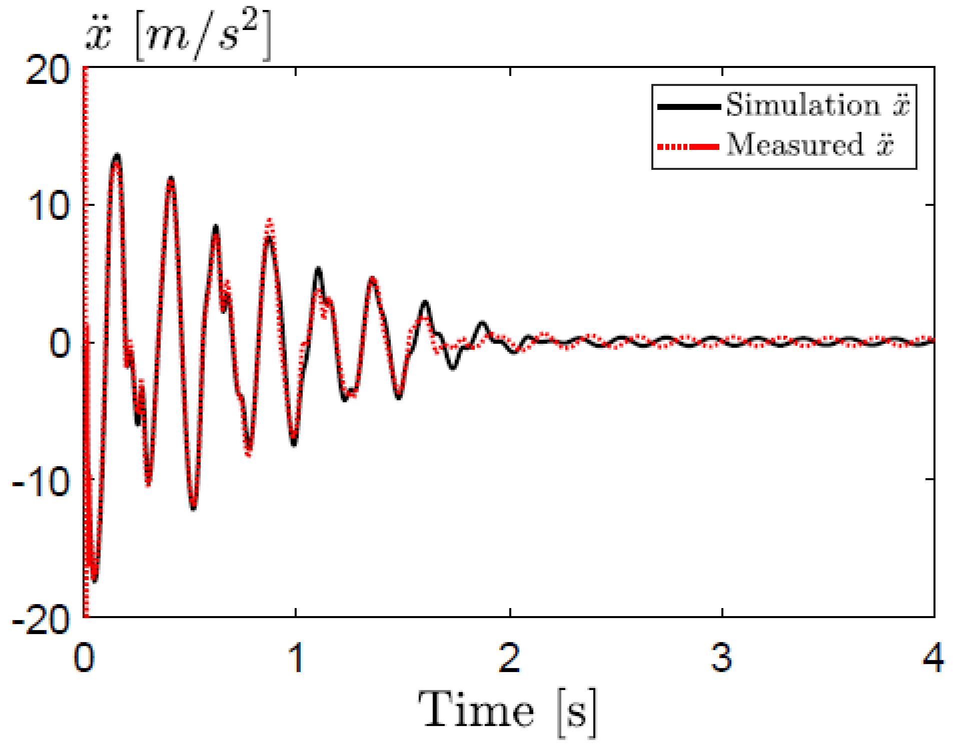


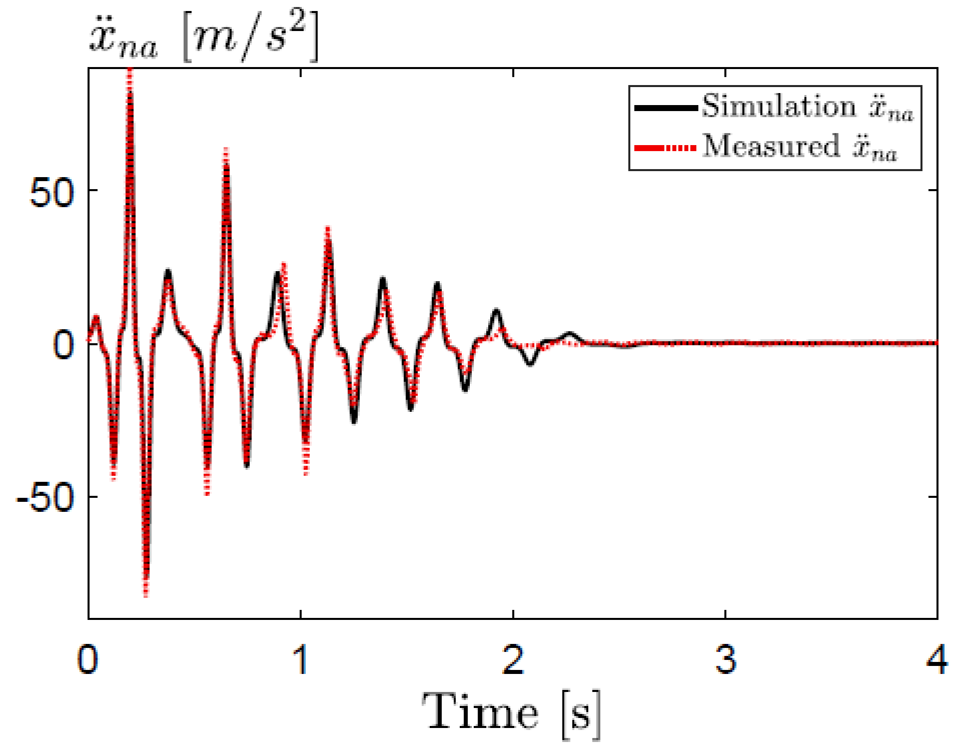
NES REALIZATION: EXPERIMENT

Without NES



With NES





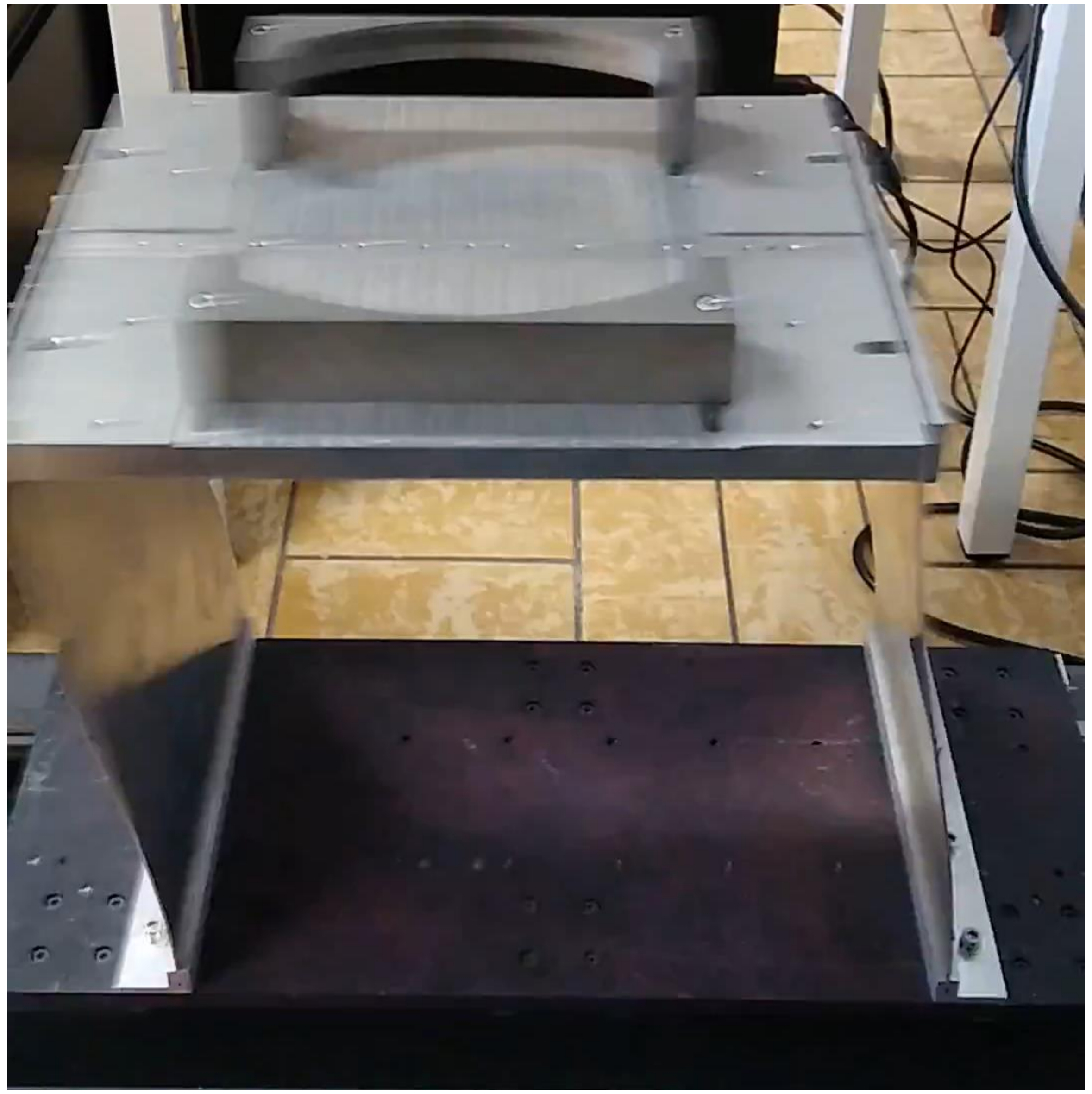
GHENT UNIVERSITY

NES REALIZATION: EXPERIMENT

Without NES

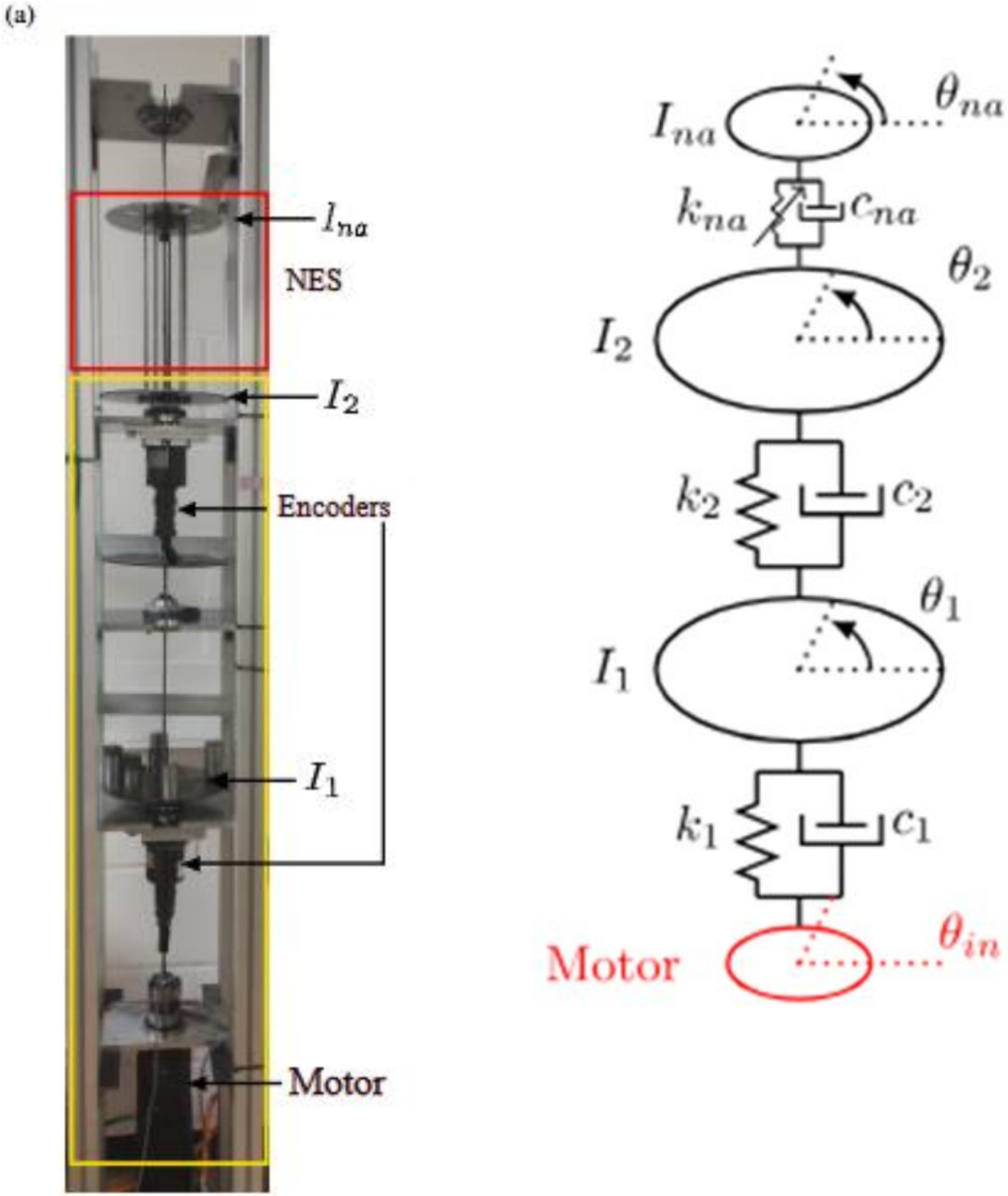
With NES

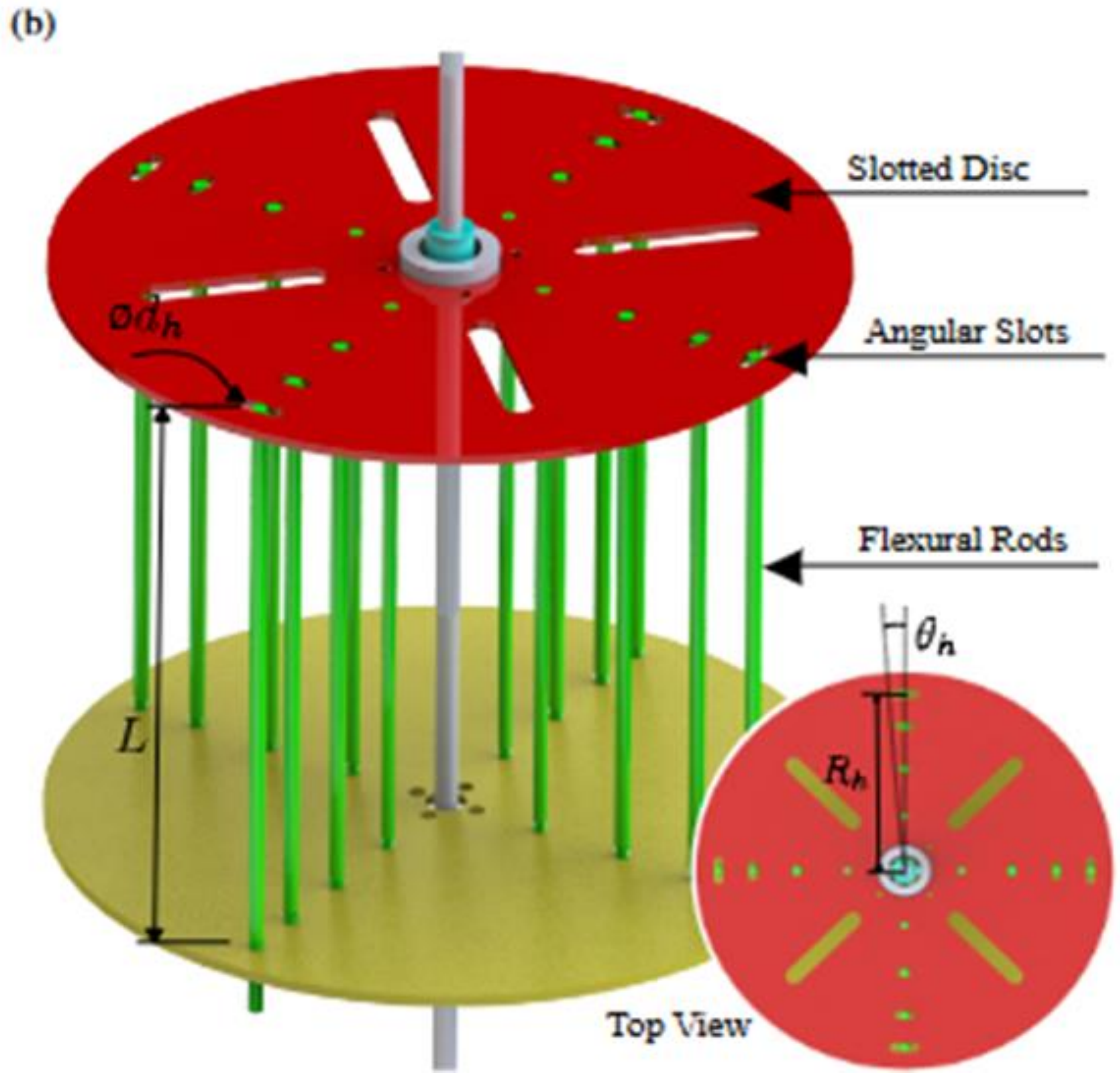
NES REALIZATION: EXPERIMENT HARMONIC



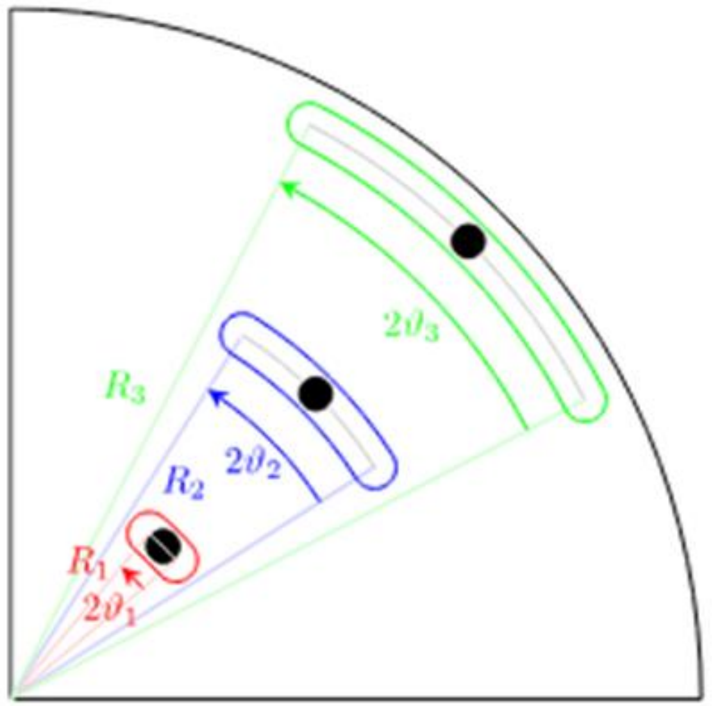
GHENT
UNIVERSITY

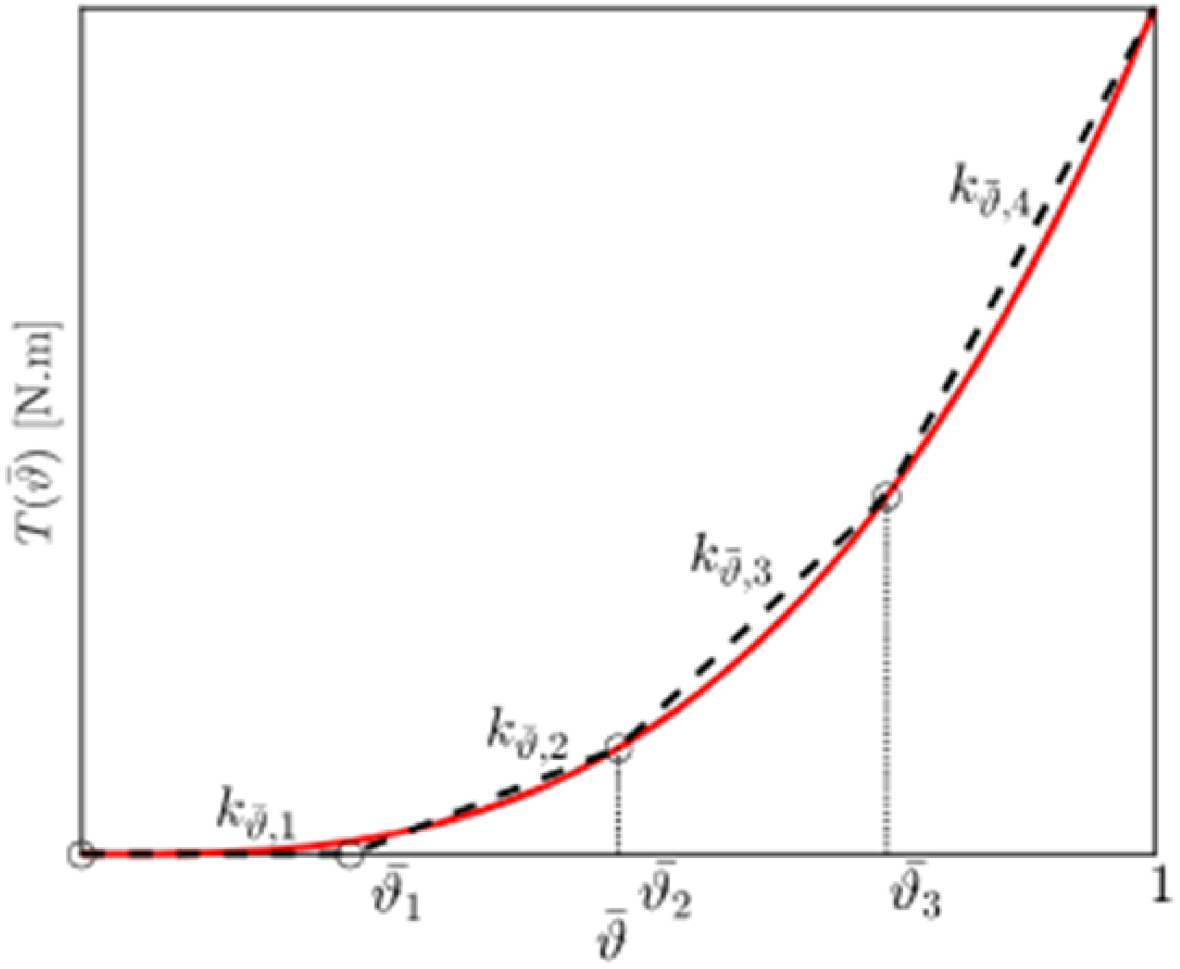
NES REALIZATION: TORSIONAL PLANT

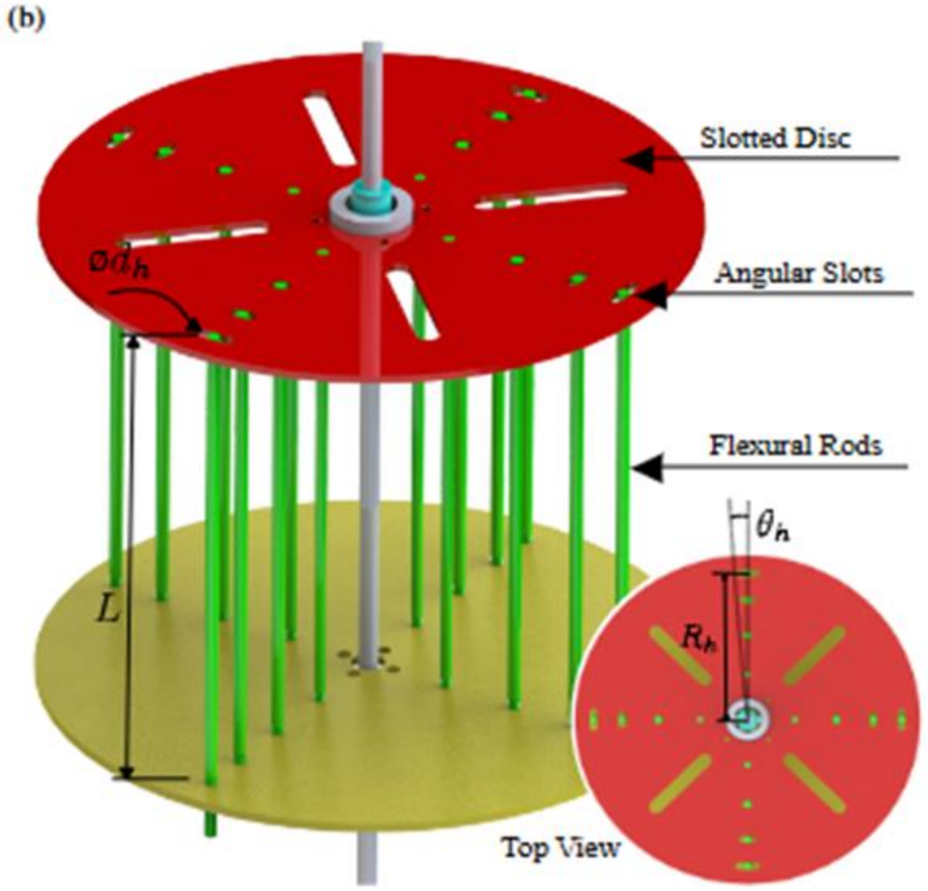


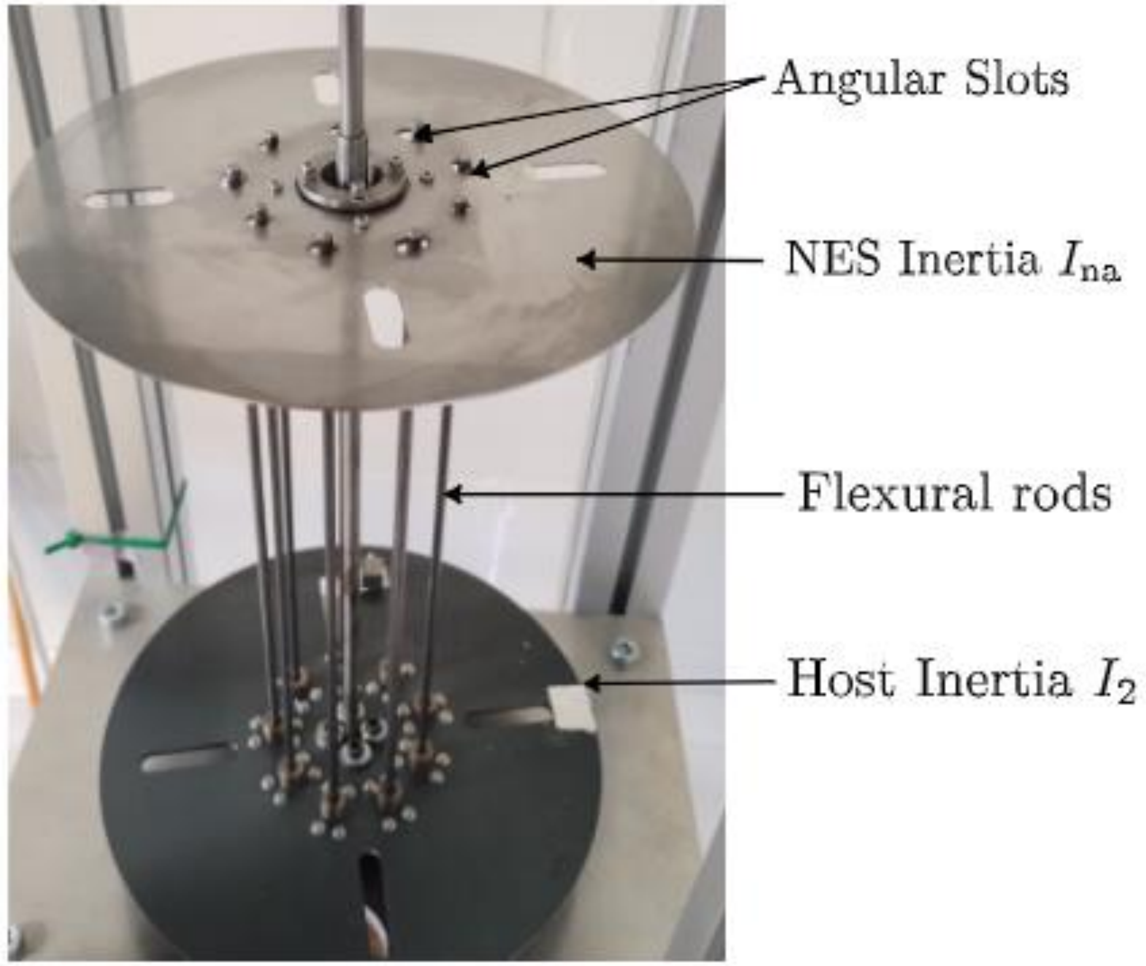


NES REALIZATION: TORSIONAL PLANT







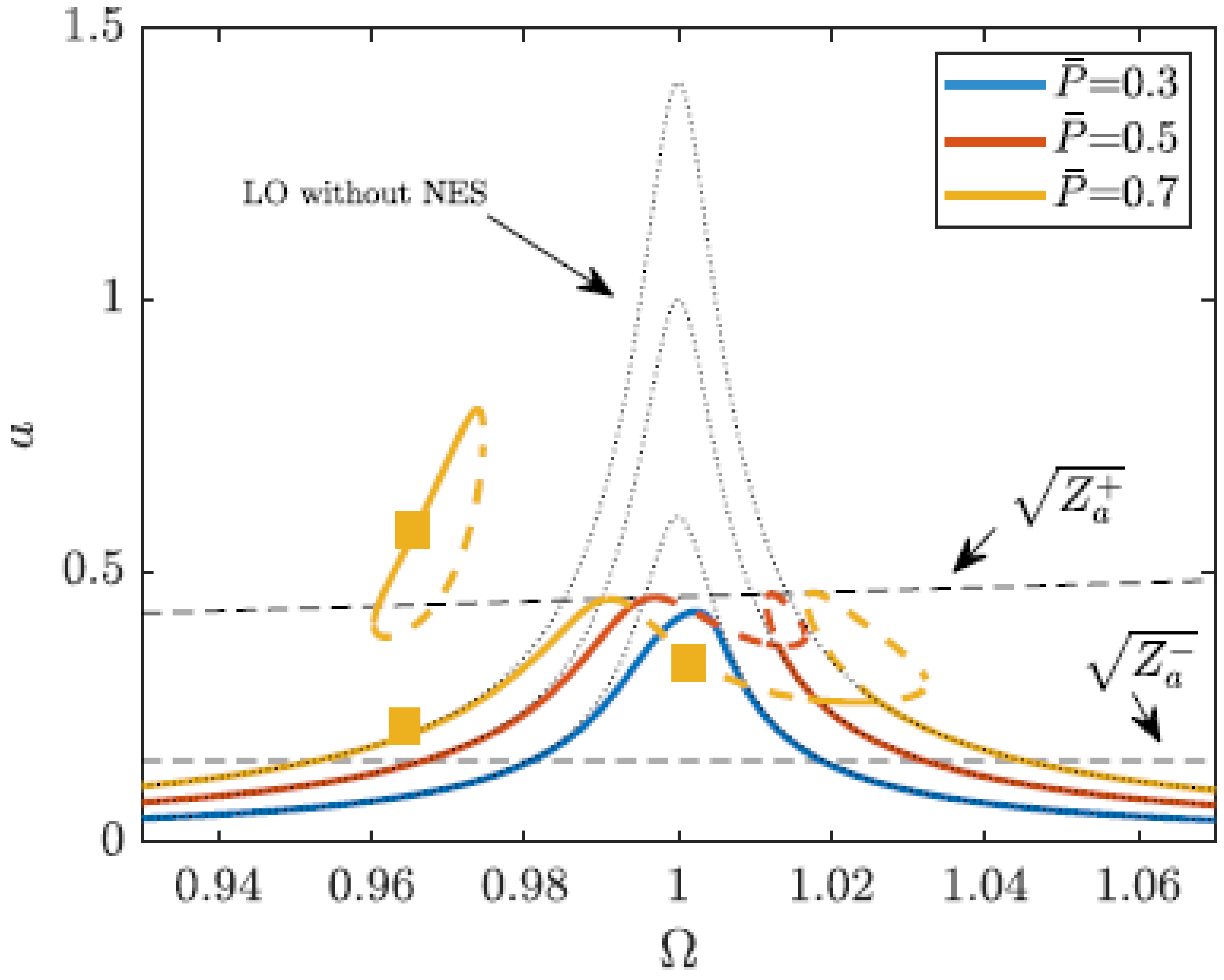


CONTENT

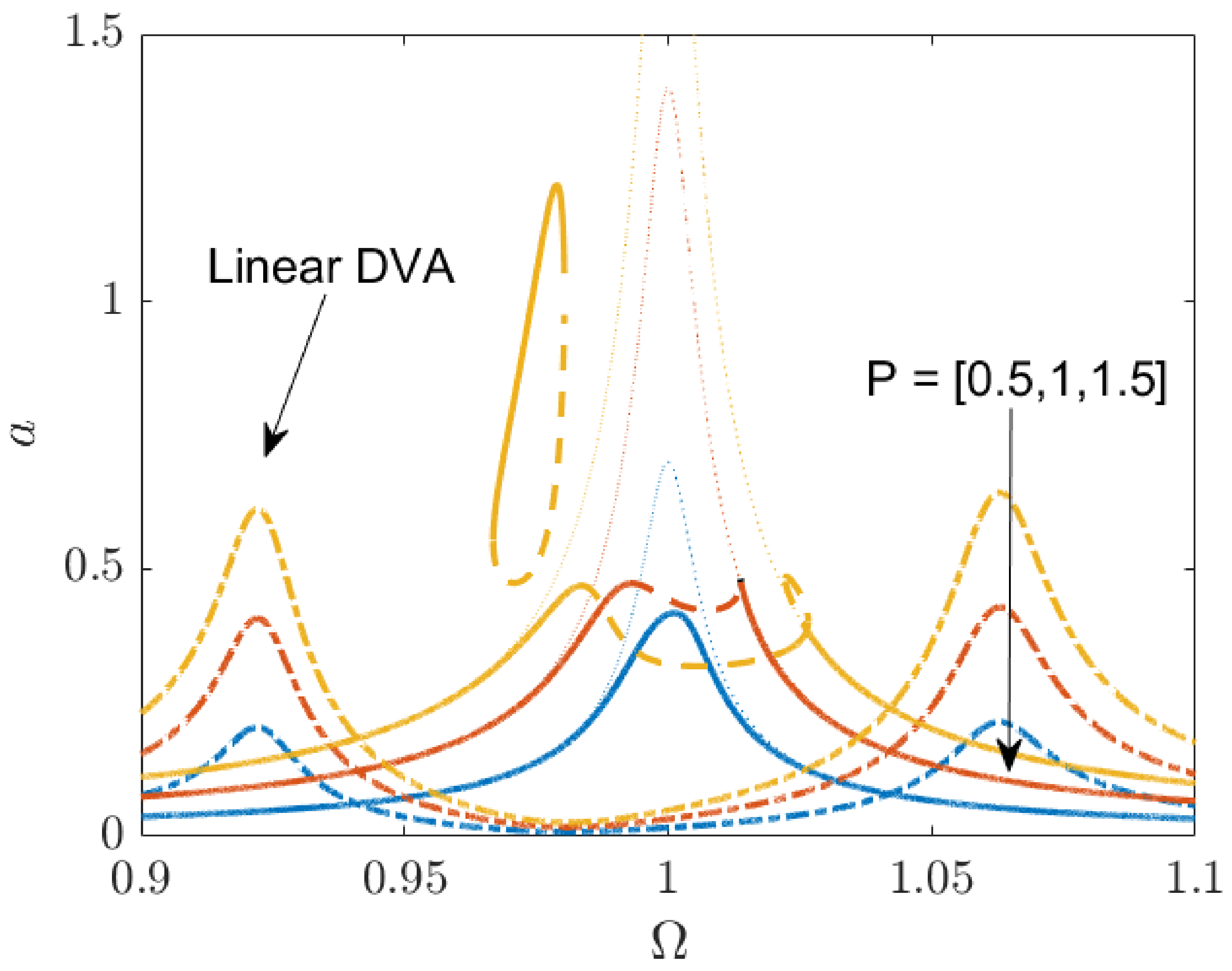
- Resonance Capture Cascade (Transient Load)
- Practical realization
- **Harmonic load: Hardening**
- Harmonic load: Softening
- Piezoelectrical NES

FORCED RESPONSE

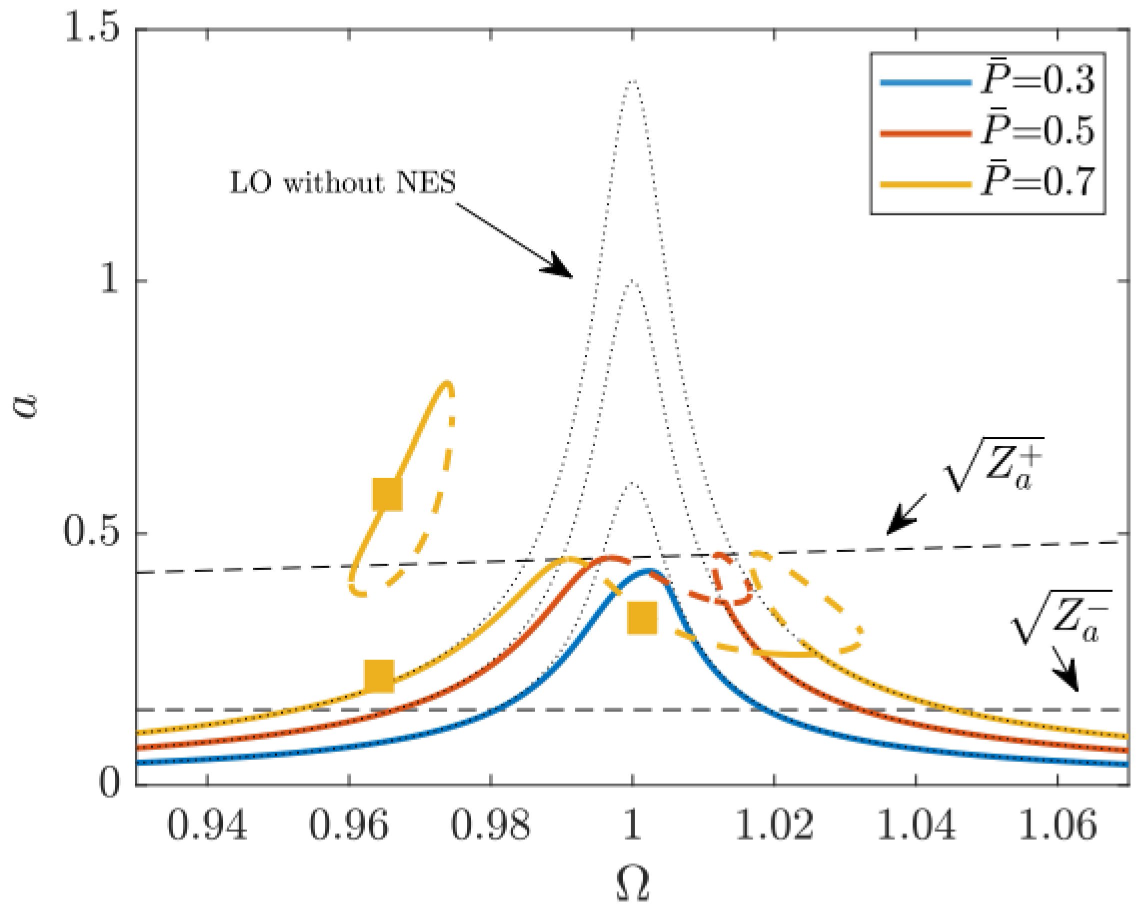
Kevin Dekemele, Tailored nonlinear stiffness and geometric damping: Applied to a bistable vibration absorber, International Journal of Non-Linear Mechanics, 2023, https://doi.org/10.1016/j.ijnonlinmec.2023.104548.

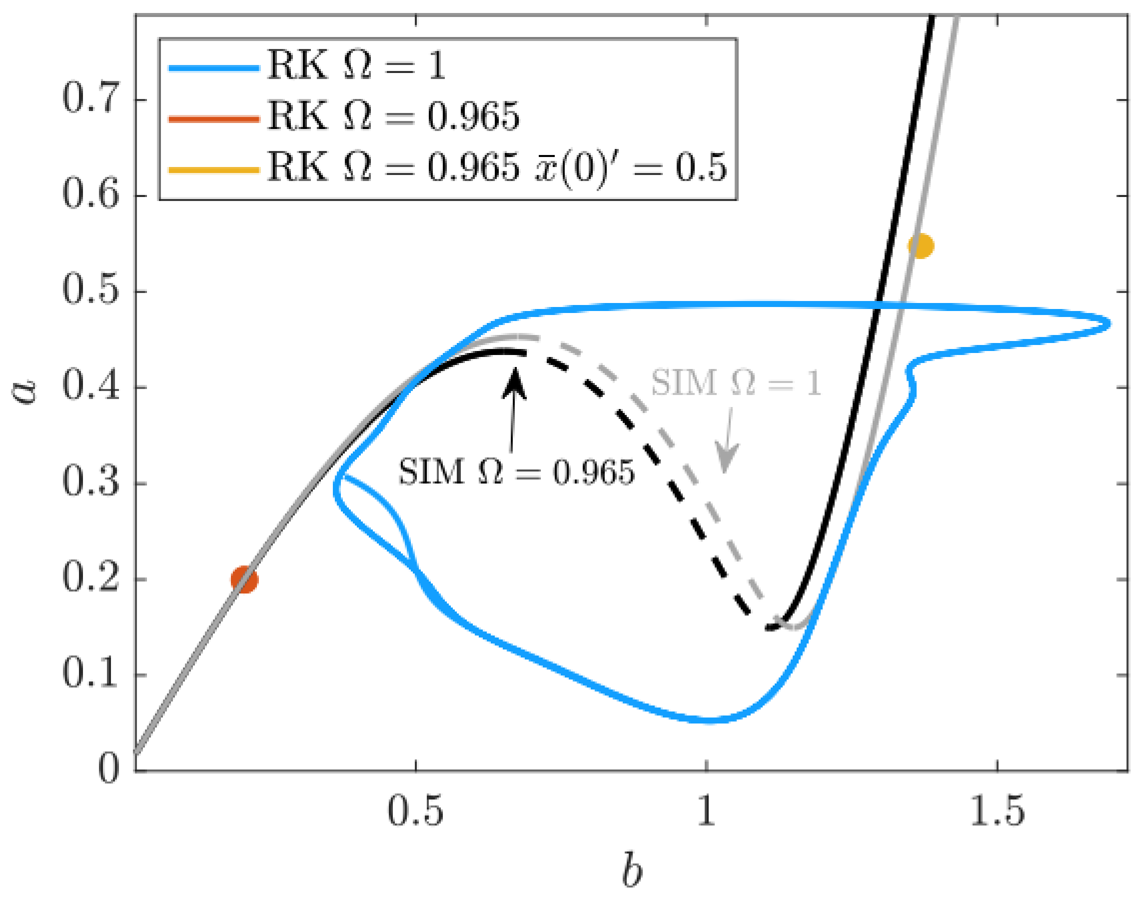


NES: Saturating and Isolated response

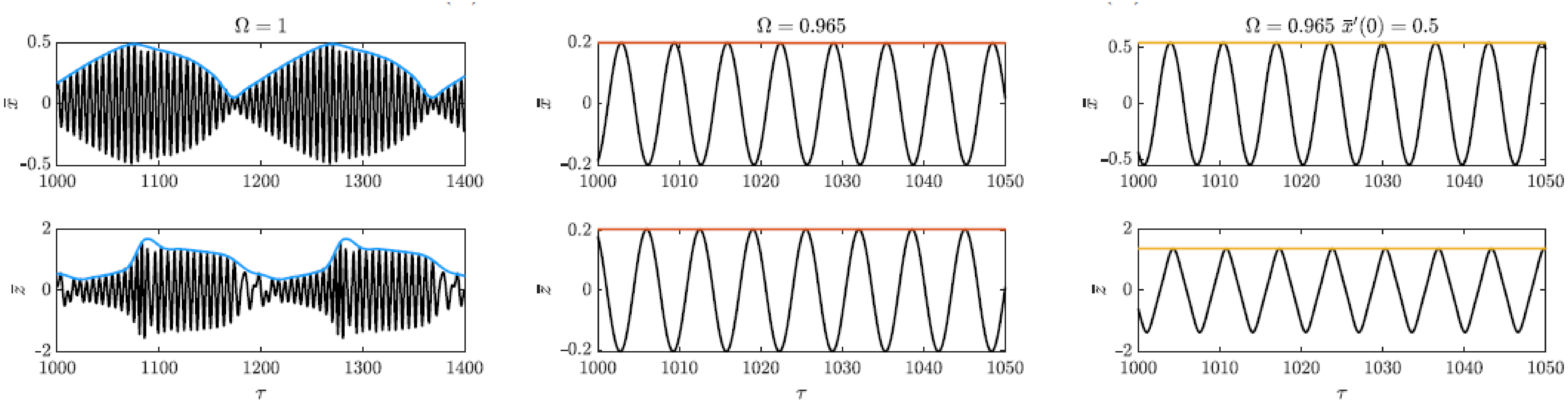


Linear DVA: Scale with force, minimum near resonance

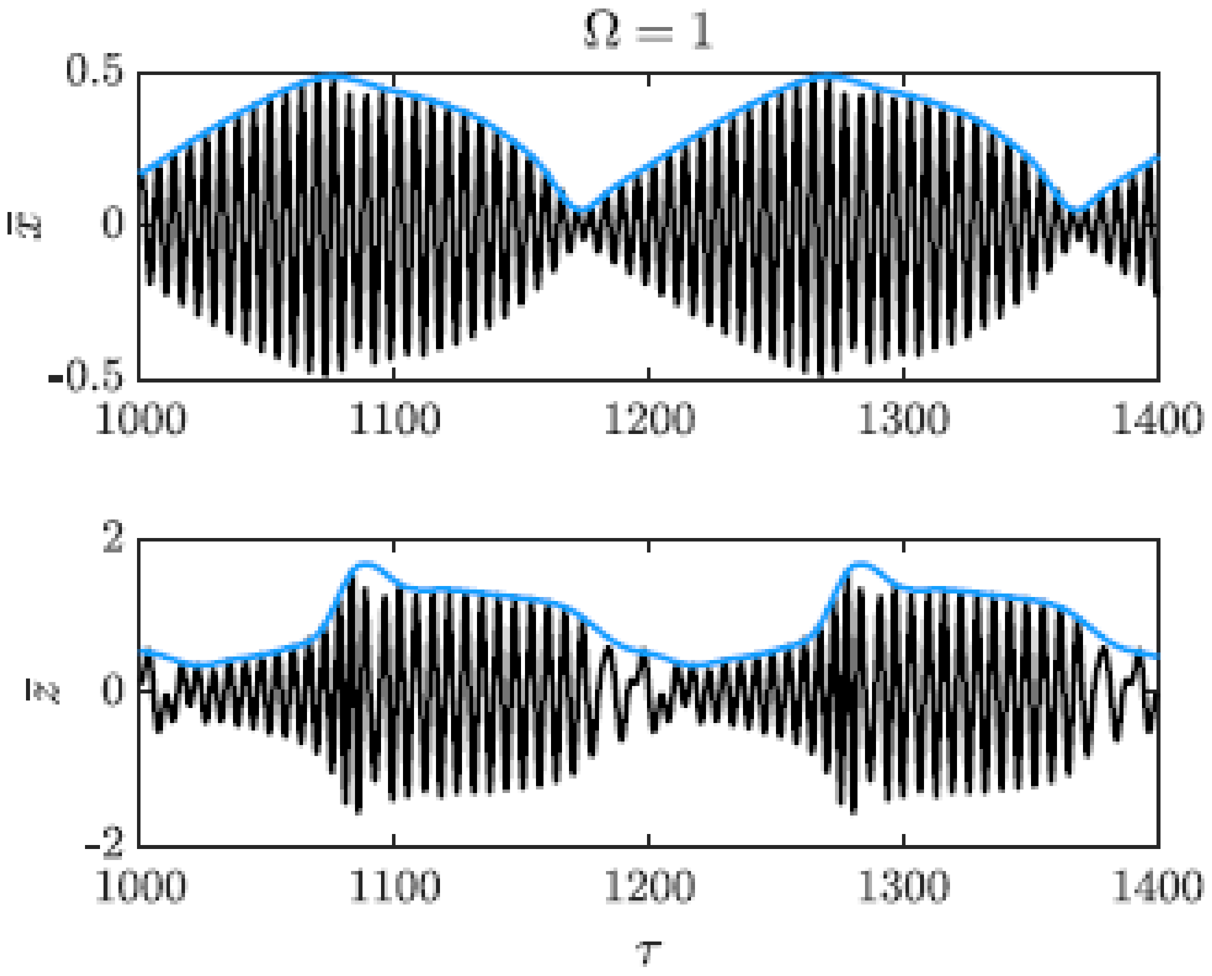


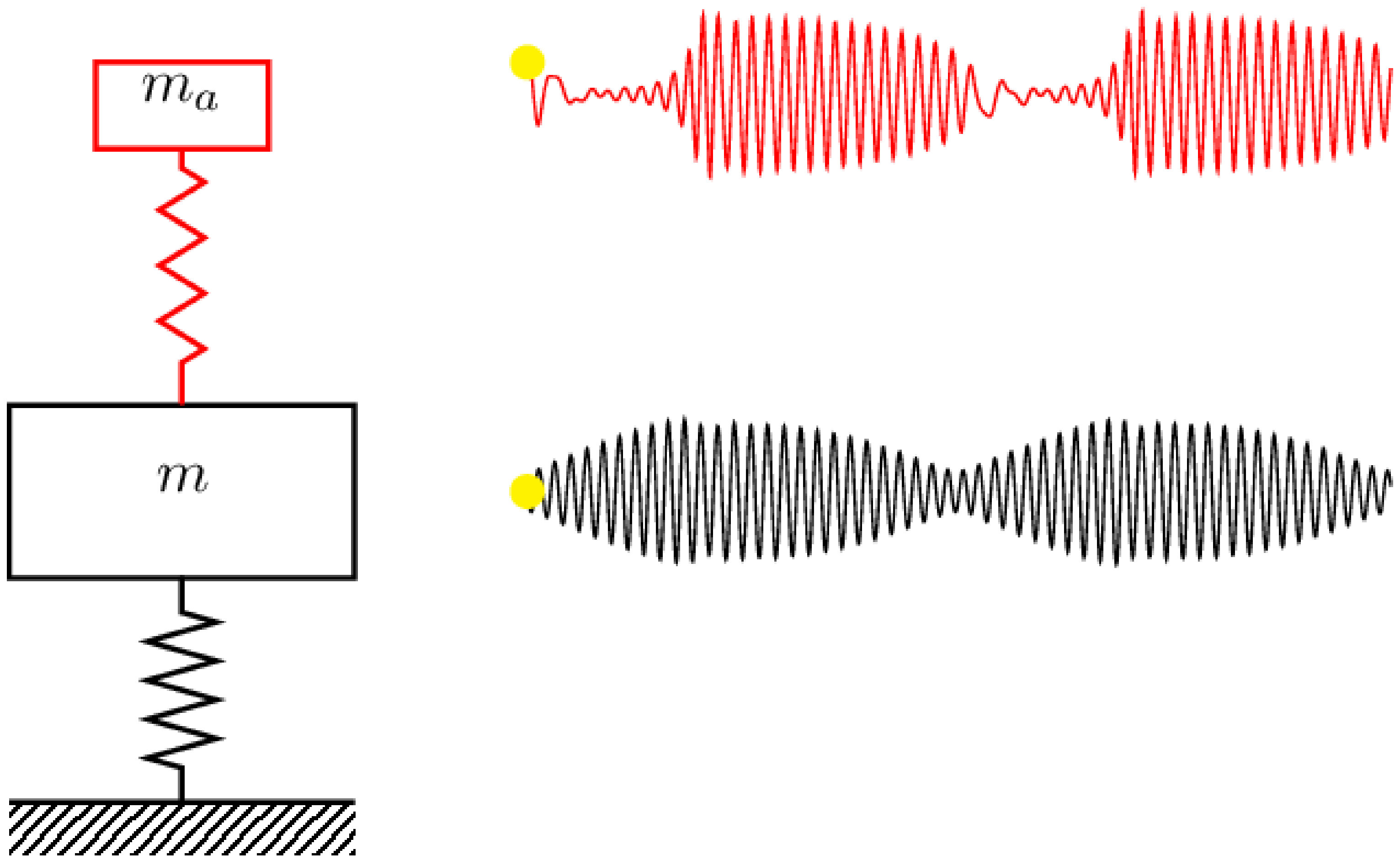


Time simulation



QUASI-PERIODIC VIBRATIONS





GHENT UNIVERSITY

QUASI-PERIODIC VIBRATIONS

GHENT
UNIVERSITY

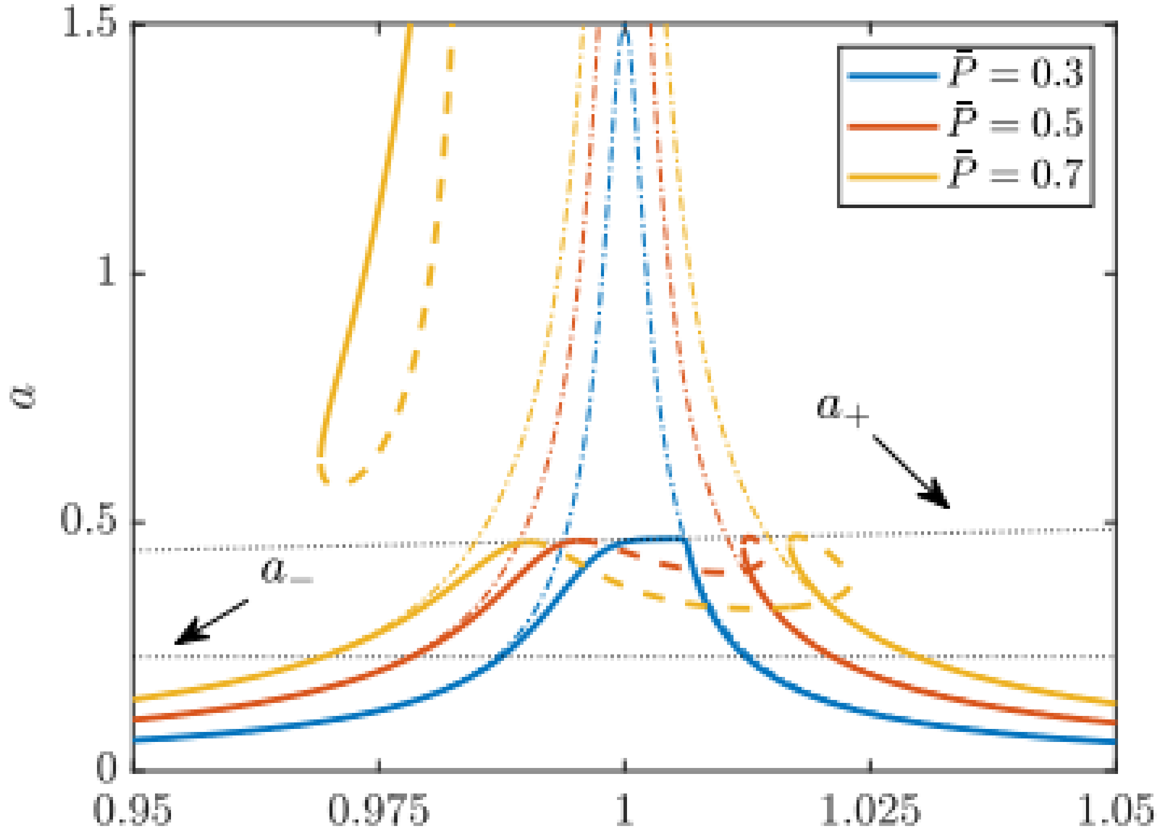
CONTENT

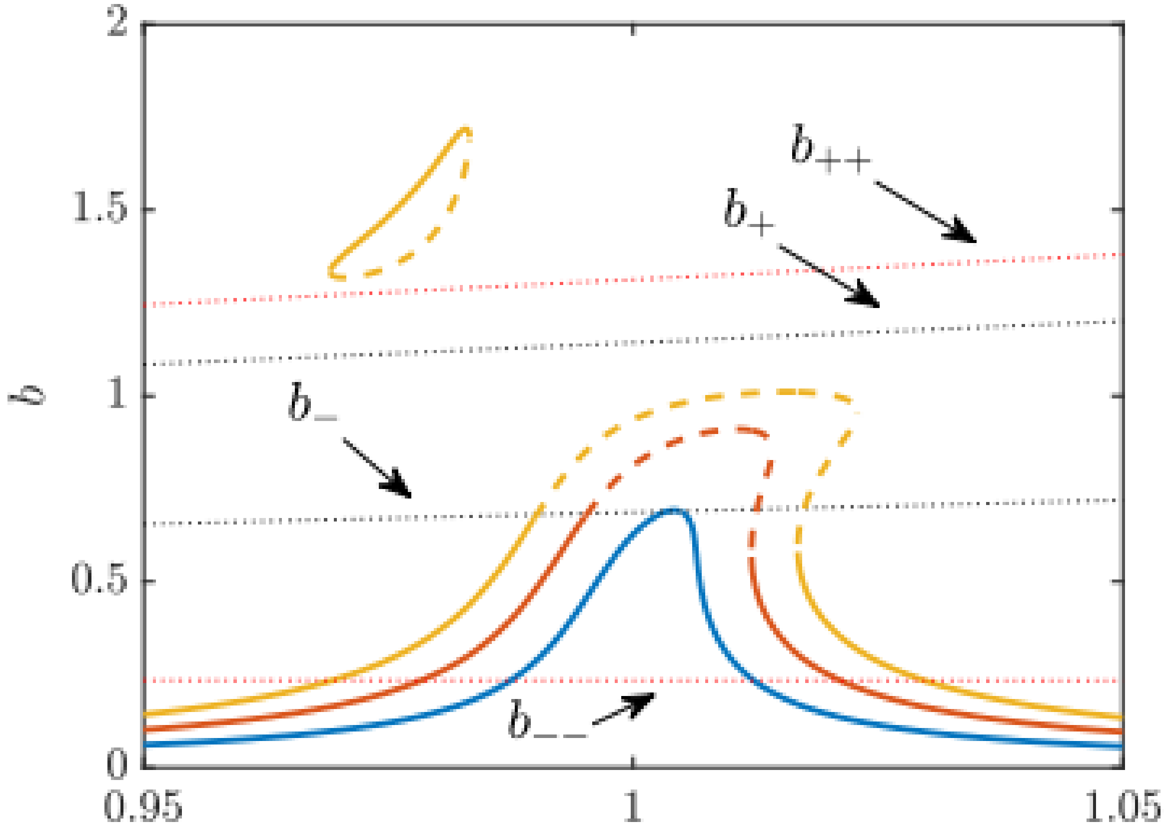
- Resonance Capture Cascade (Transient Load)
- Practical realization
- Harmonic load: Hardening
- **Harmonic load: Softening**
- Piezoelectrical NES

GHENT UNIVERSITY

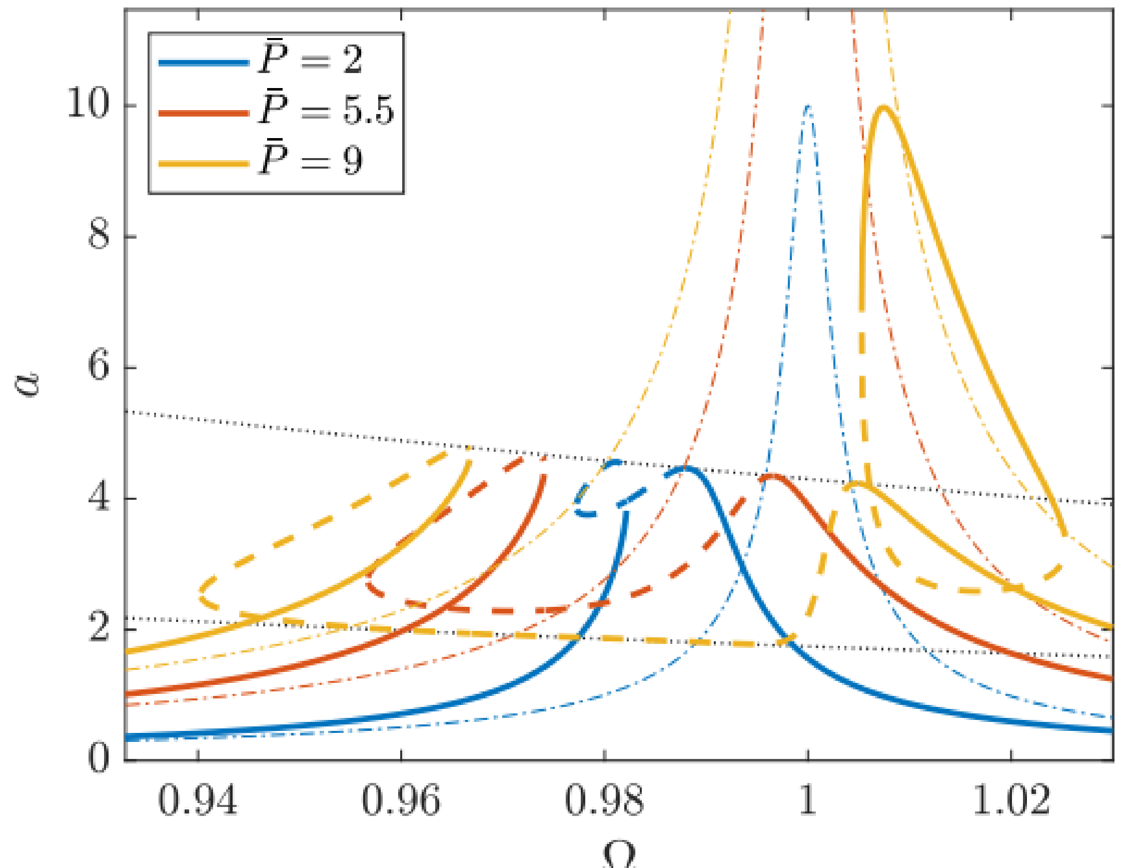
SOFTENING NONLINEAR ENERGY SINK

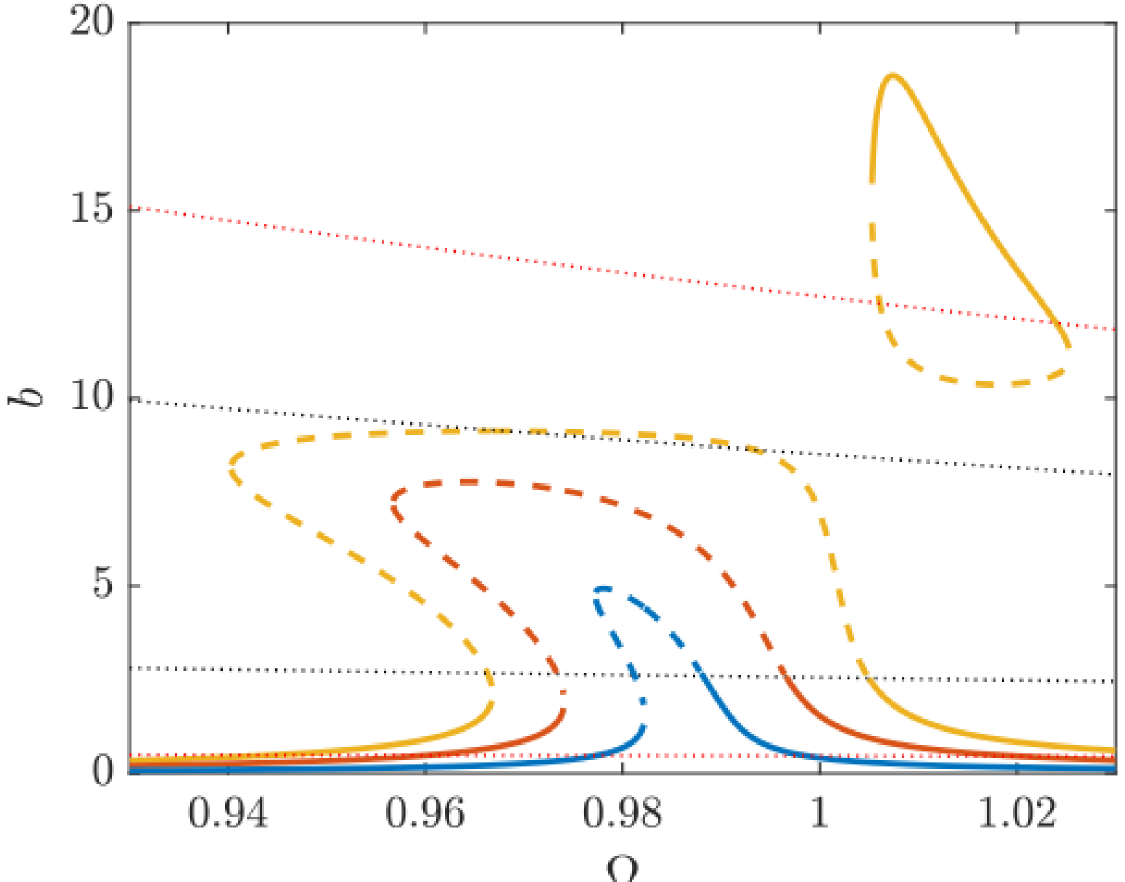
Hardening





Softening

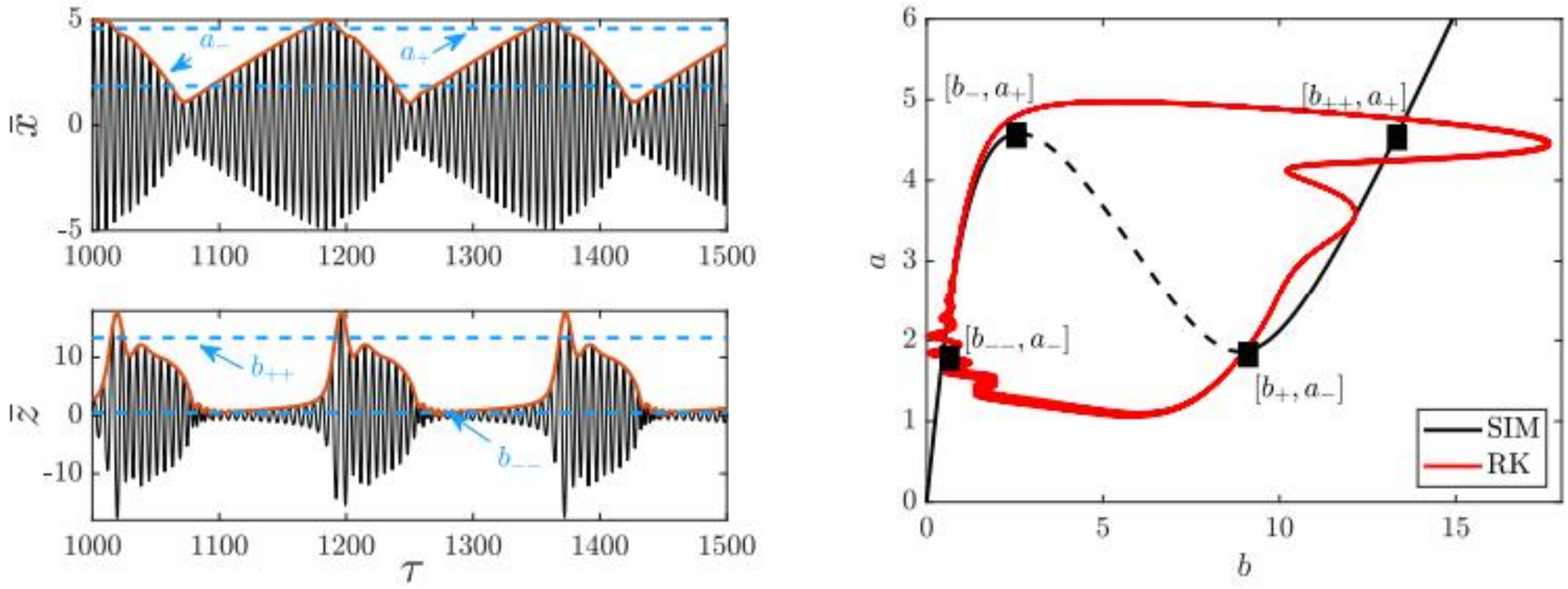




MŰEGYETEM 1782

GHENT UNIVERSITY

TIME SIGNALS: QUASI PERIODIC

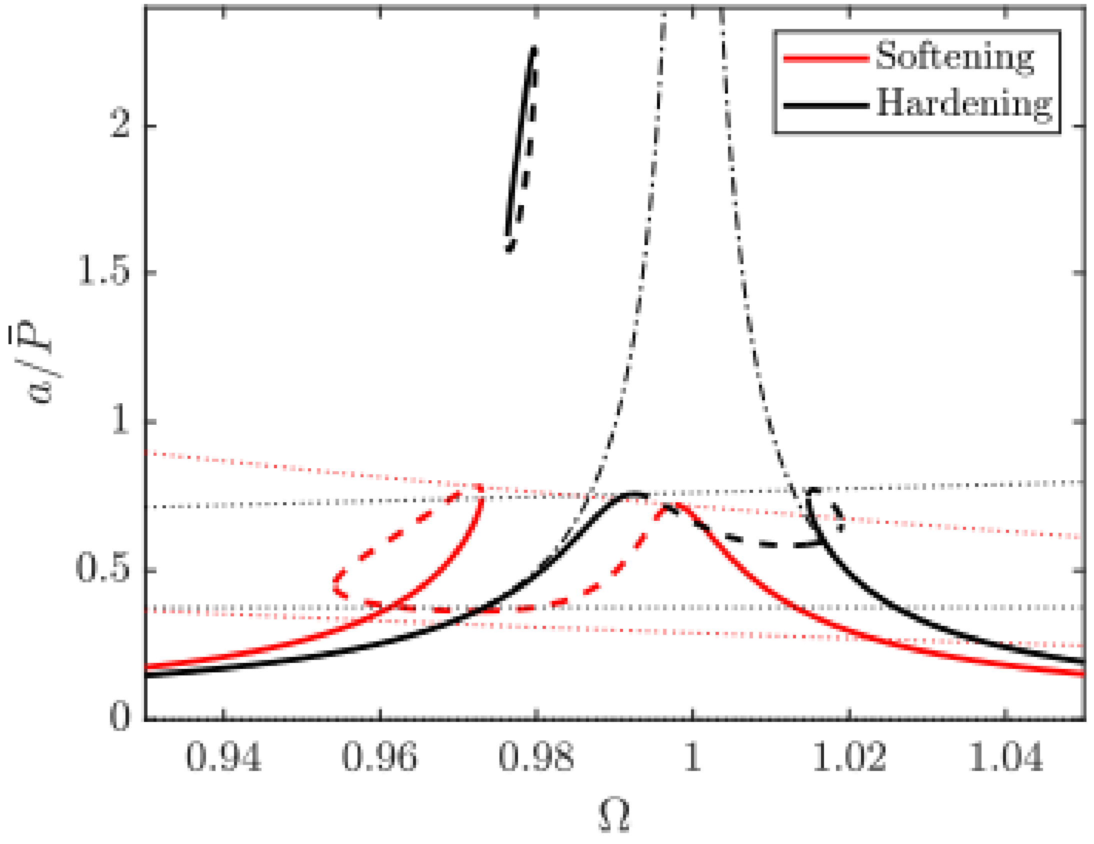


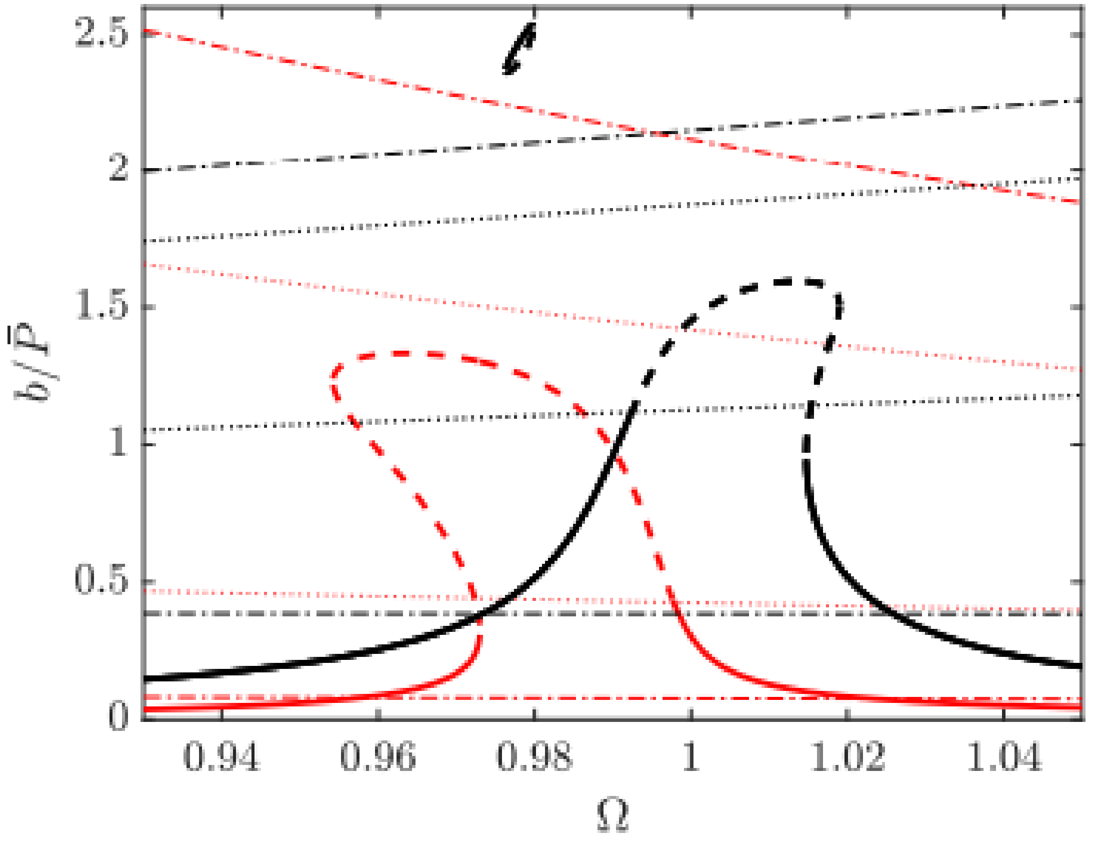
GHENT UNIVERSITY

HARDENING VS SOFTENING: WHO'S BETTER?

Same saturation

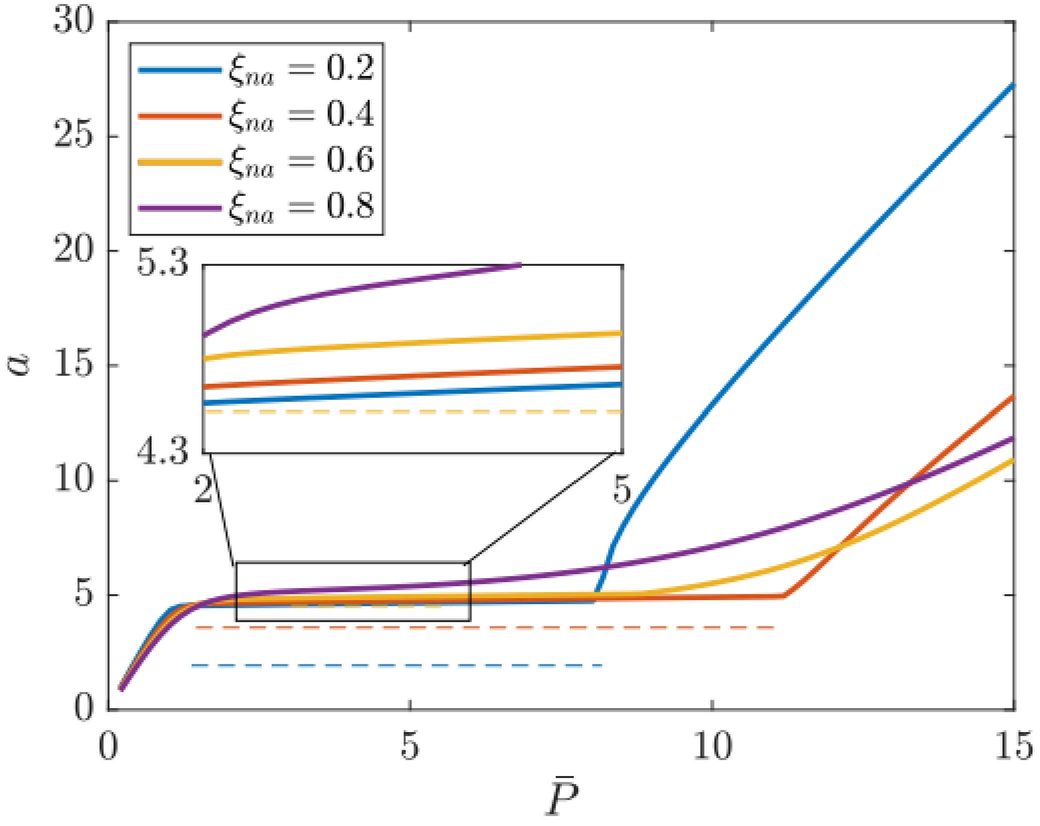
No isola!

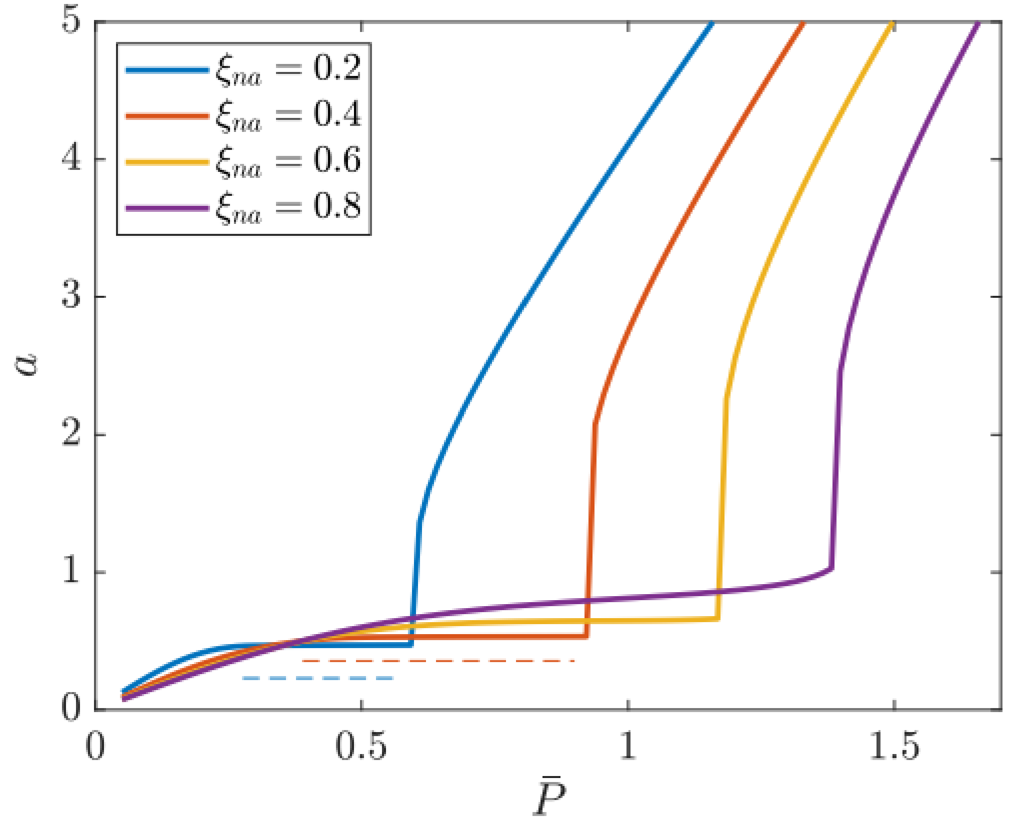




Larger force

range for saturation

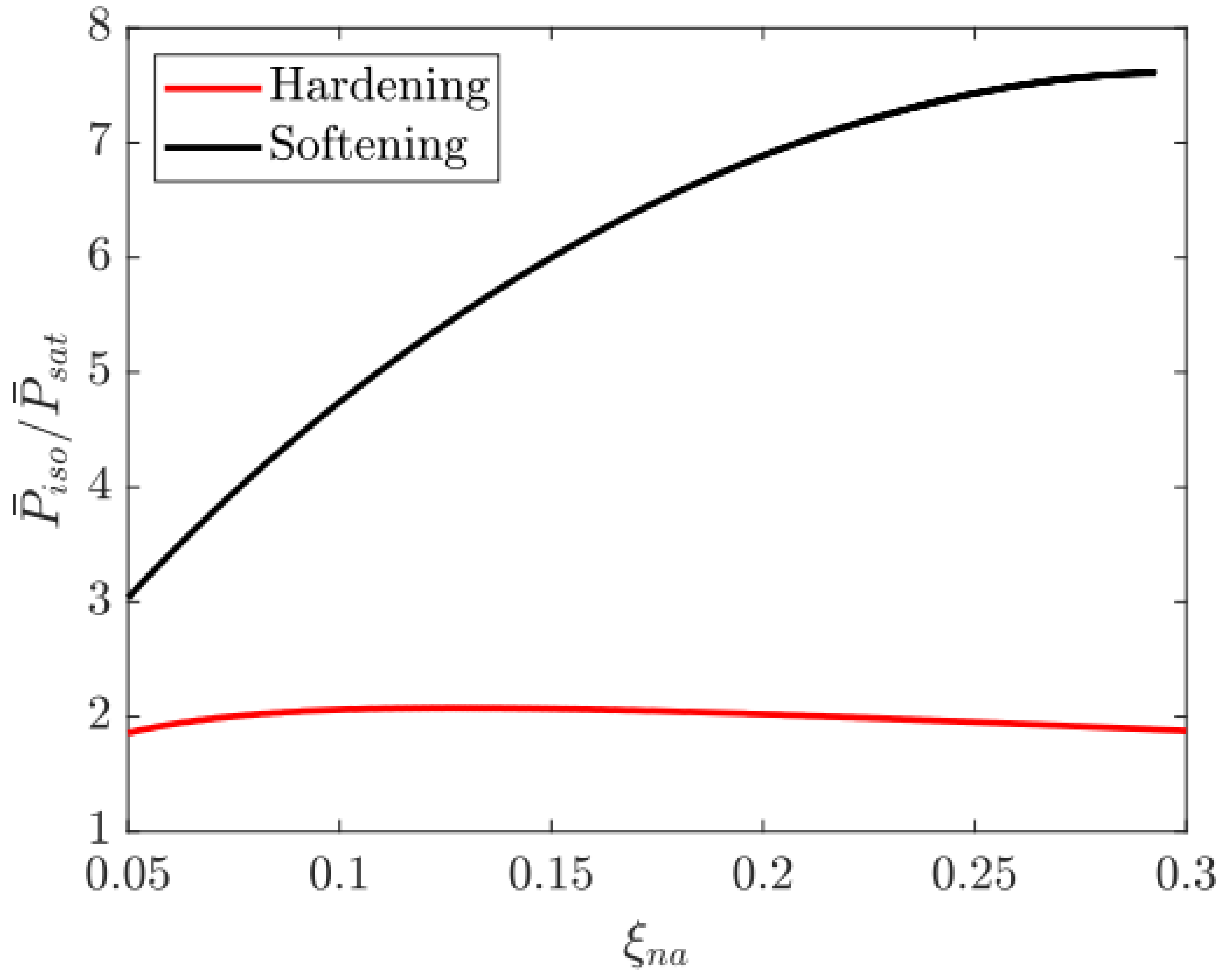




FORCE RANGE INDEX

Ratio of: Force when Isola appear/ Force when saturation starts

Larger force range for saturation



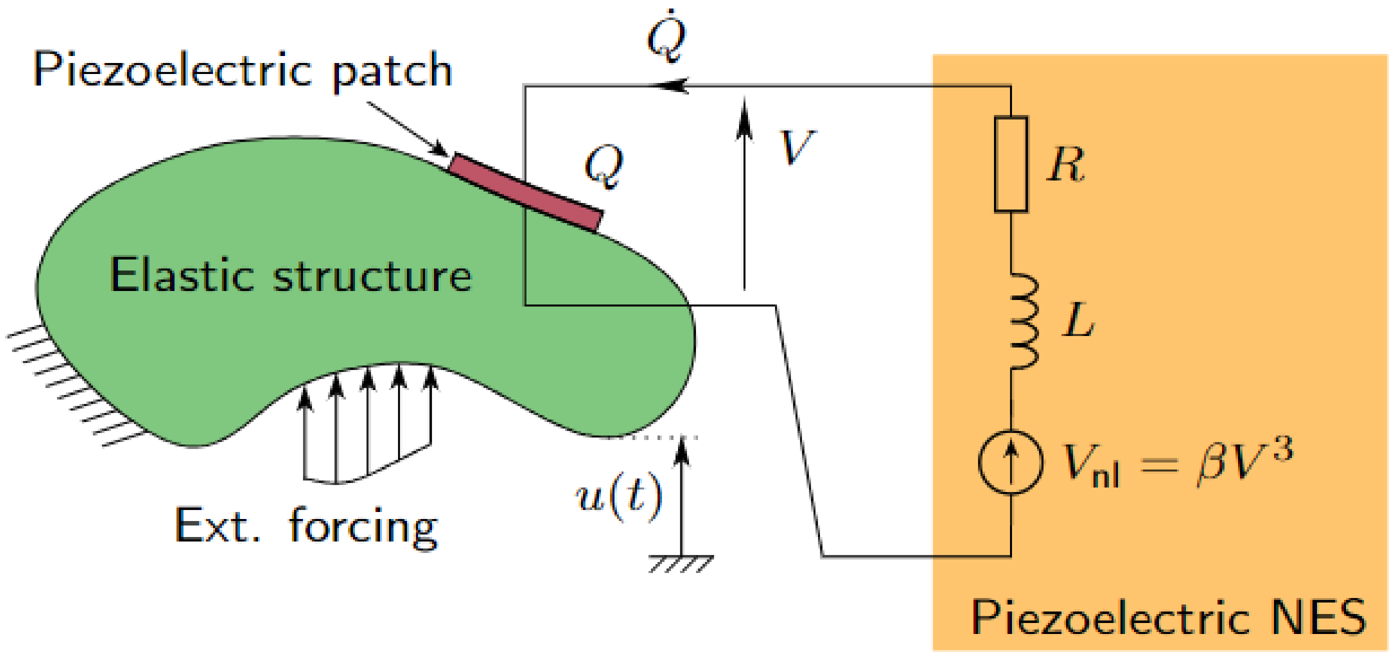
(c) Force Range Index

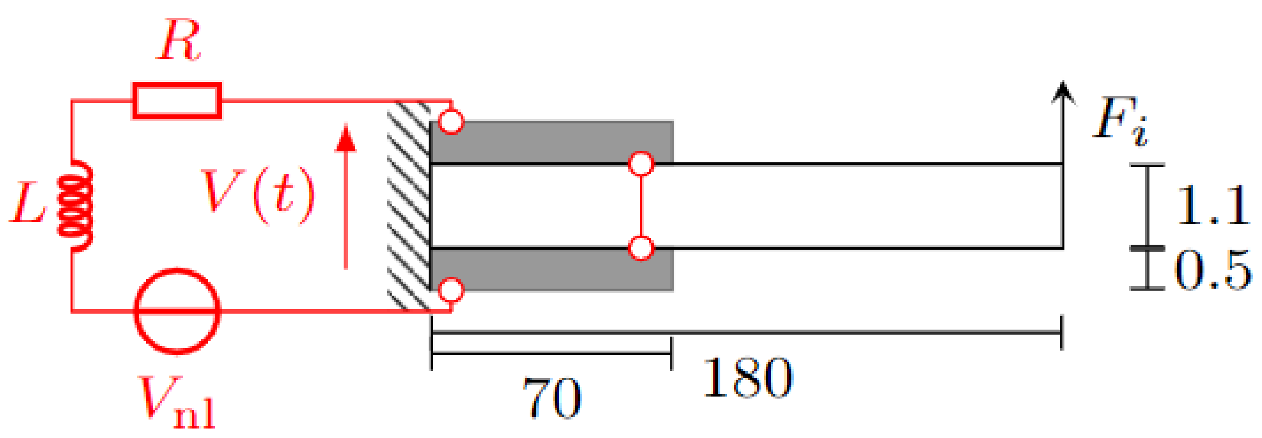
CONTENT

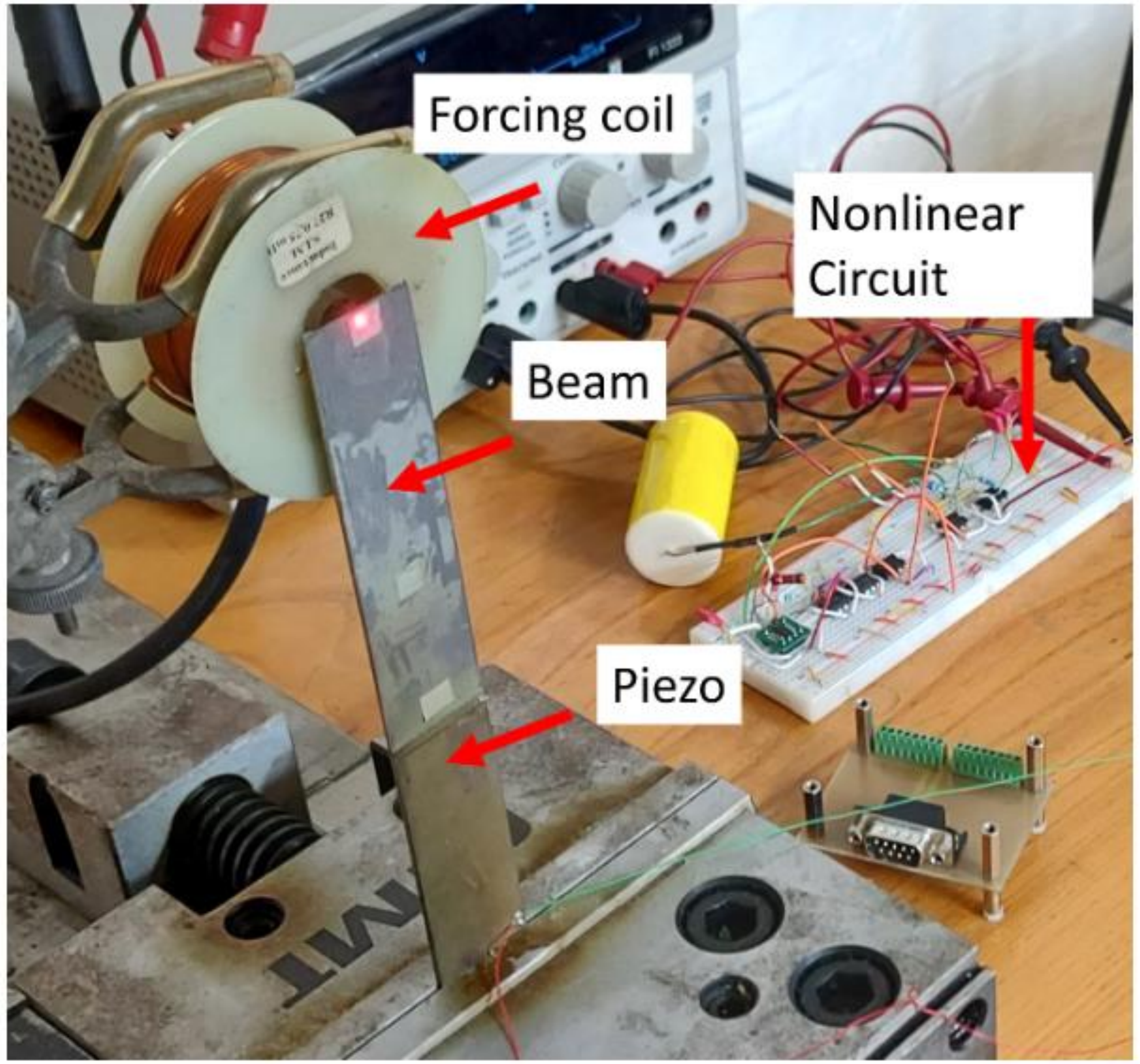
– Resonance Capture Cascade (Transient Load)
– Practical realization
– Harmonic load: Hardening
– Harmonic load: Softening
– **Piezoelectrical NES**

GHENT UNIVERSITY

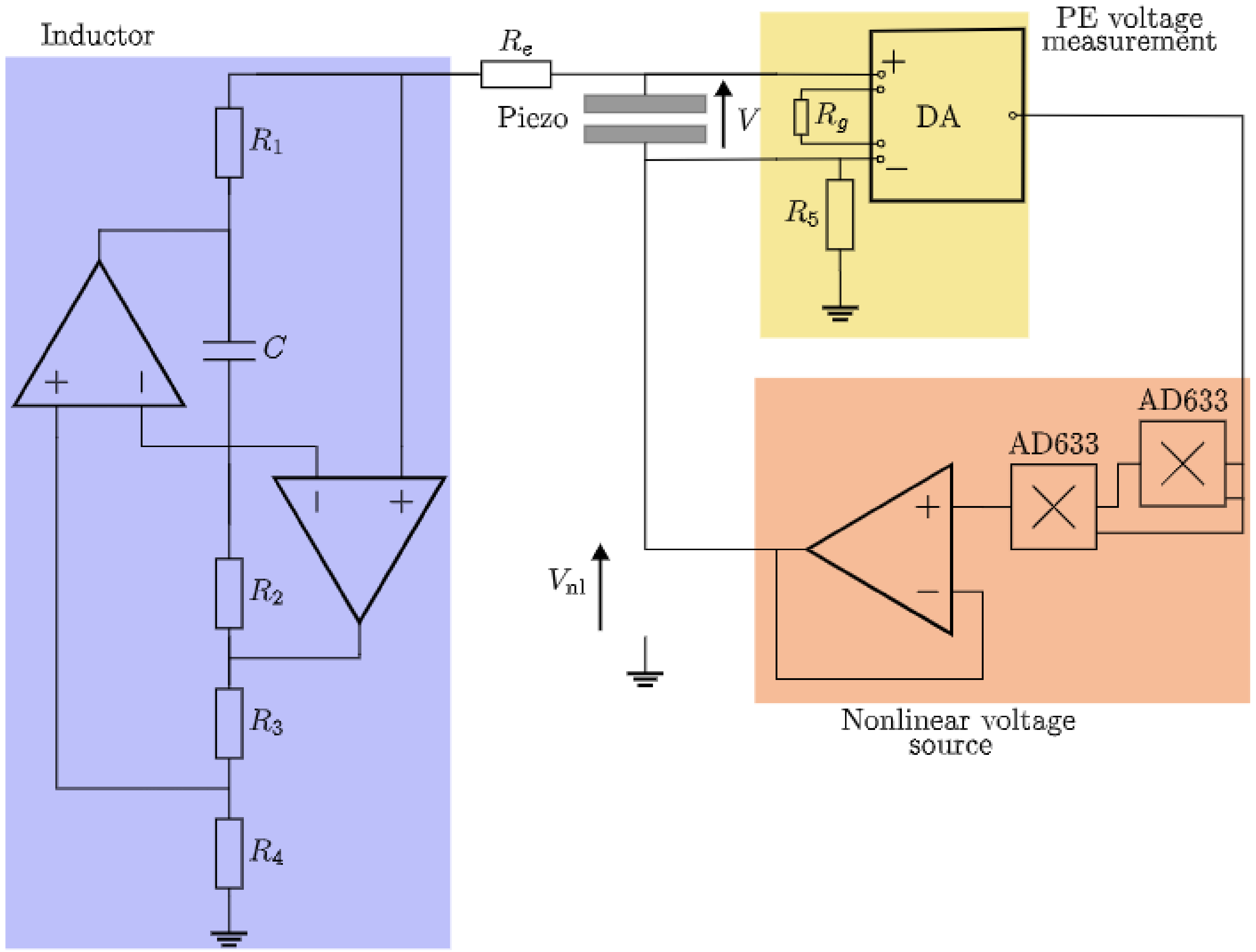
PIEZOELECTRICAL NES

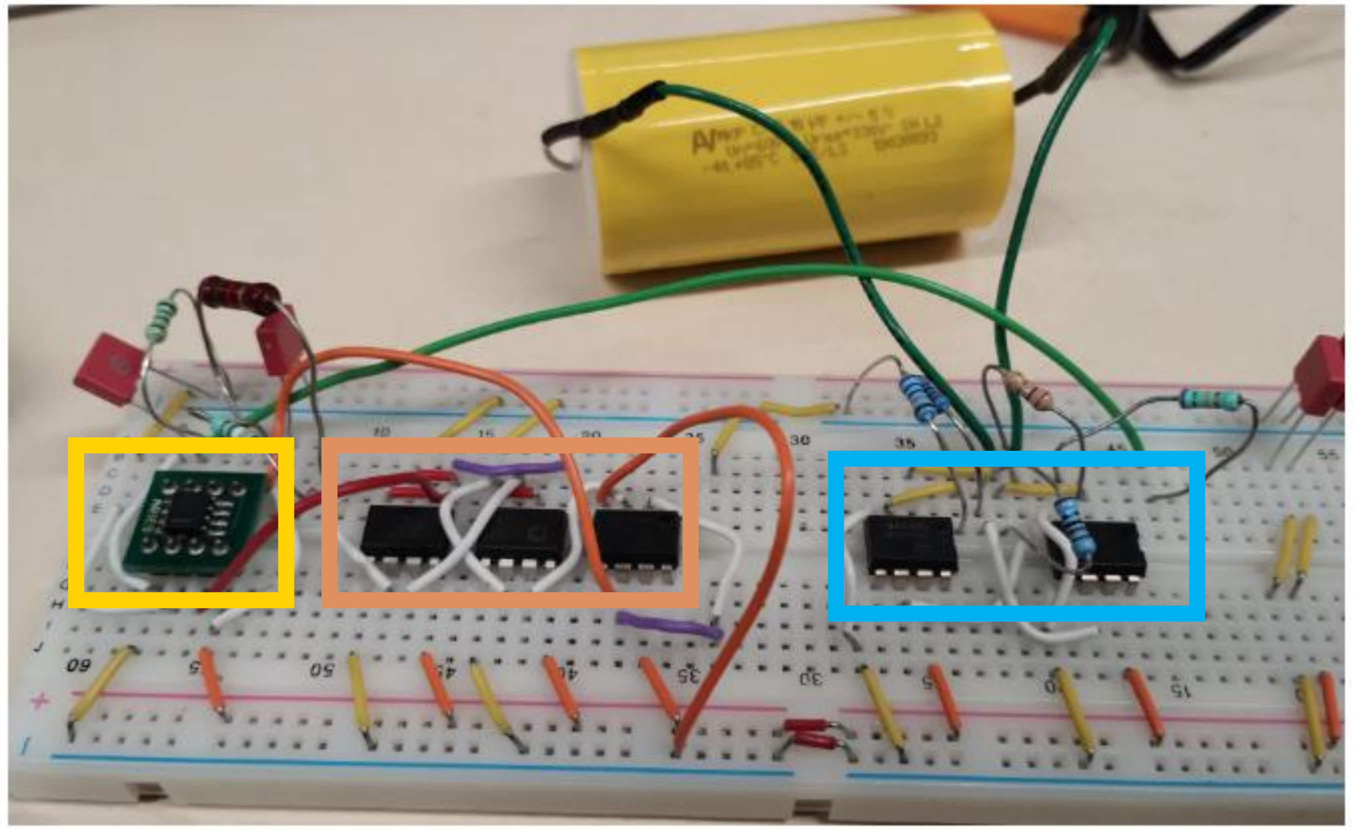






CIRCUIT NONLINEAR

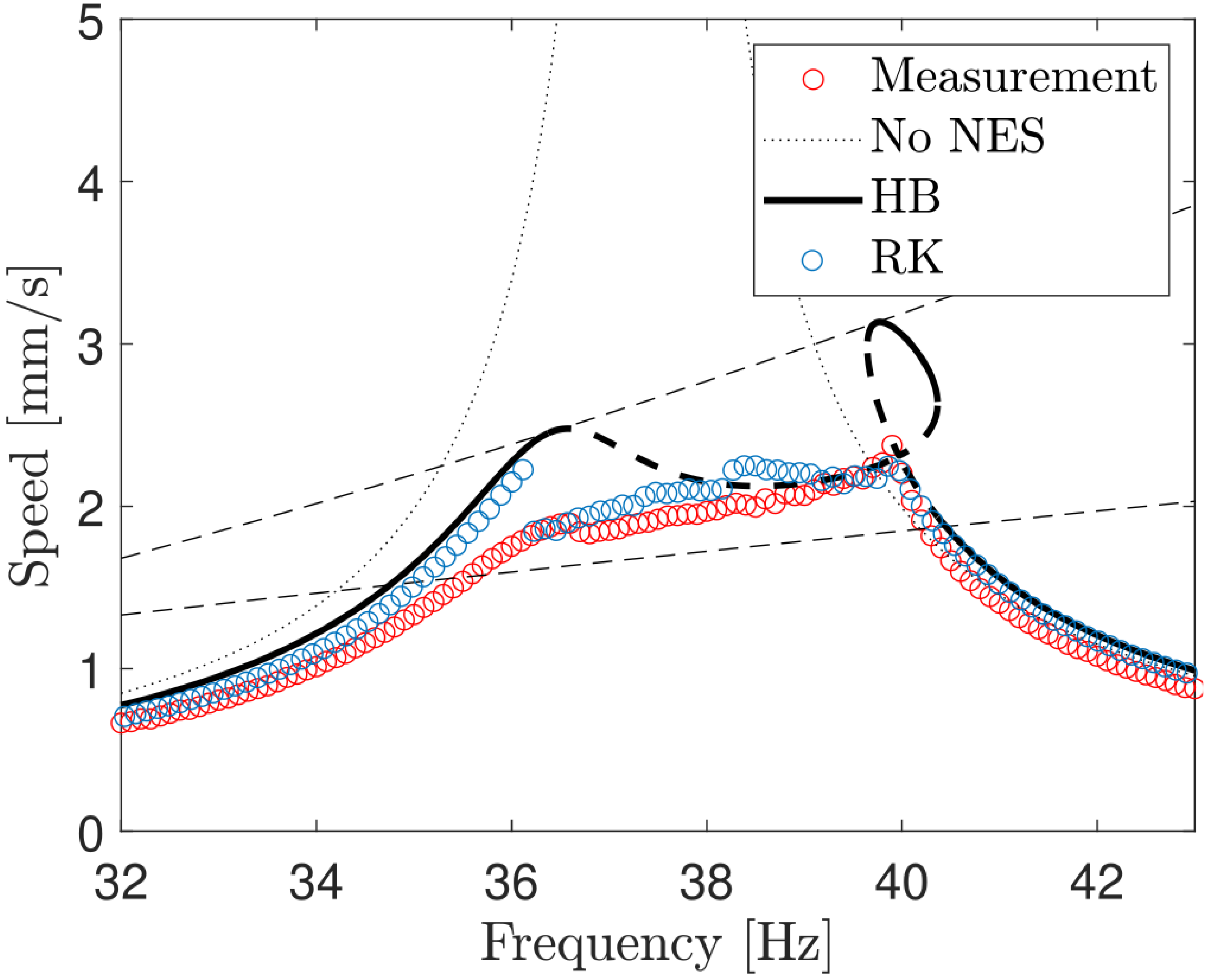




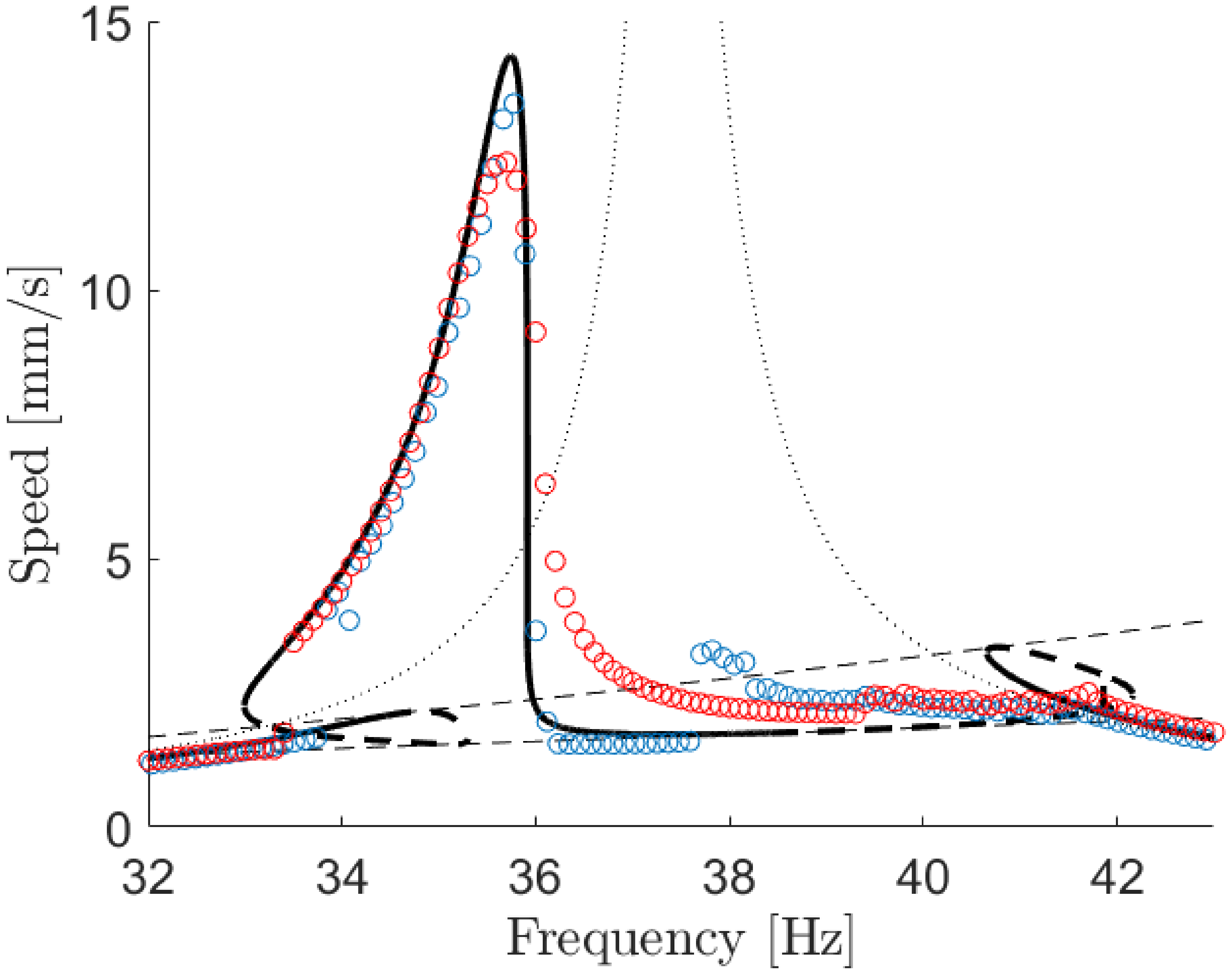
GHENT UNIVERSITY

MEASUREMENT AND THEORY

F = 0,584 mN

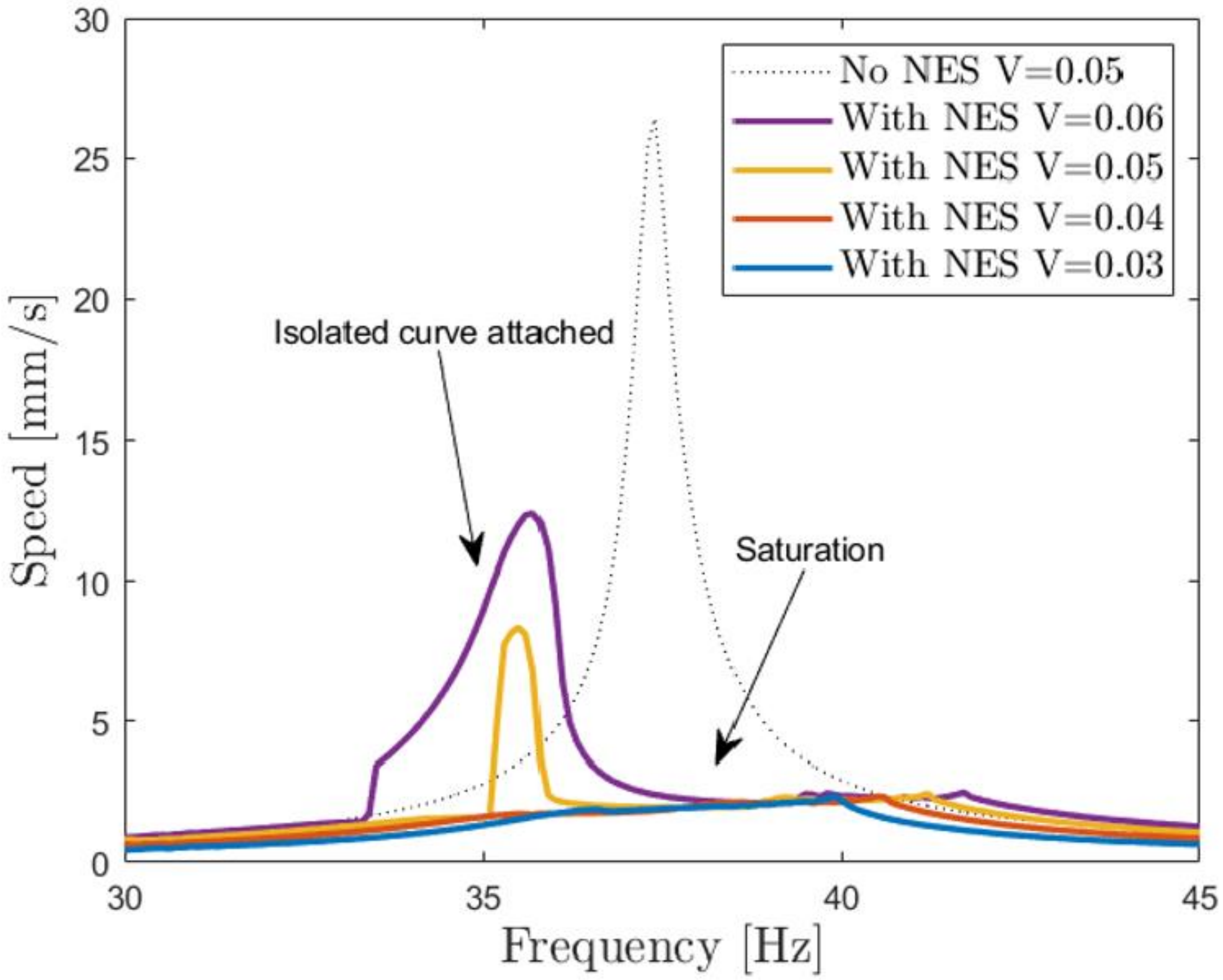


F = 0,945 mN

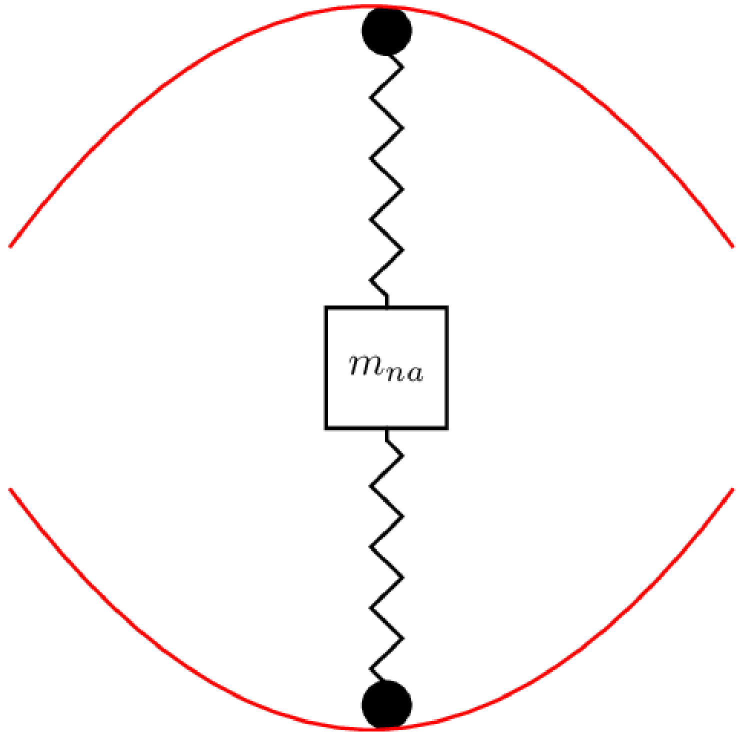


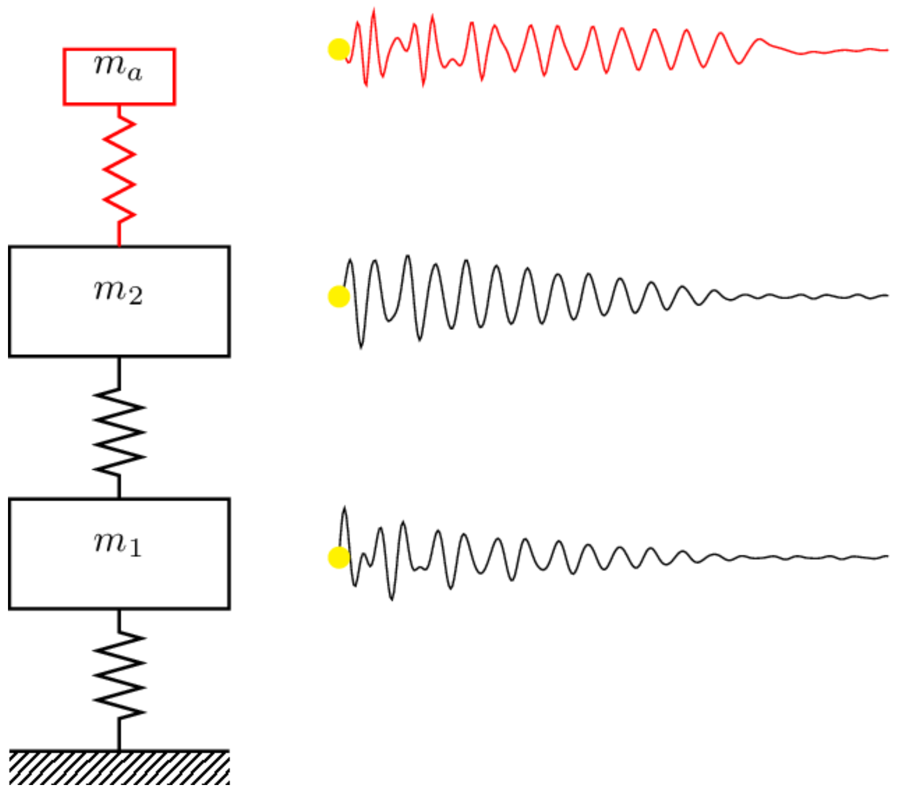
GHENT UNIVERSITY

SATURATION: EXPERIMENT

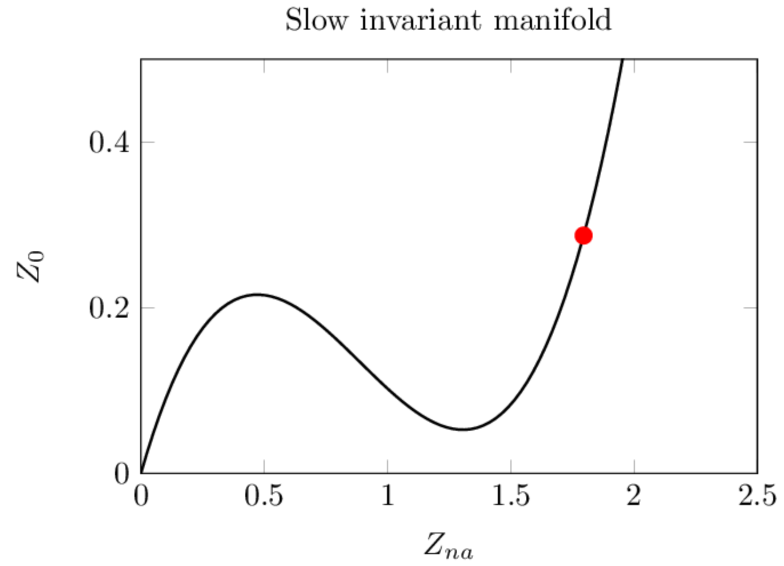


GHENT UNIVERSITY





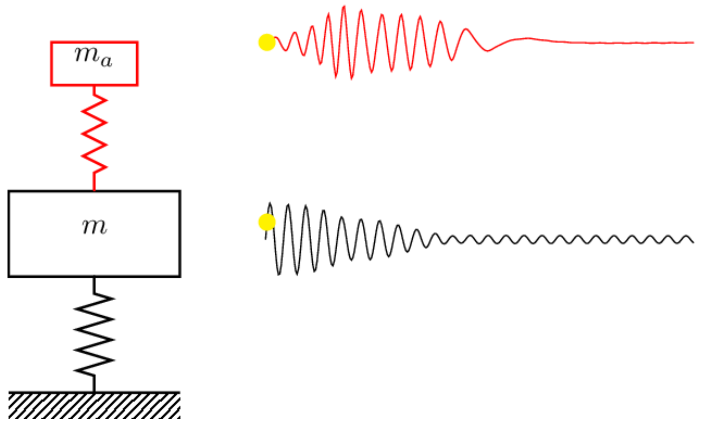
THANKS FOR LISTENING



Kevin Dekemele

kevin.dekemele@ugent.be

www.kevindekemele.com



GHENT UNIVERSITY