Technische Hochschule Wildau [FH]
Technical University of Applied Sciences

Brake Pad Design Against Brake Squeal

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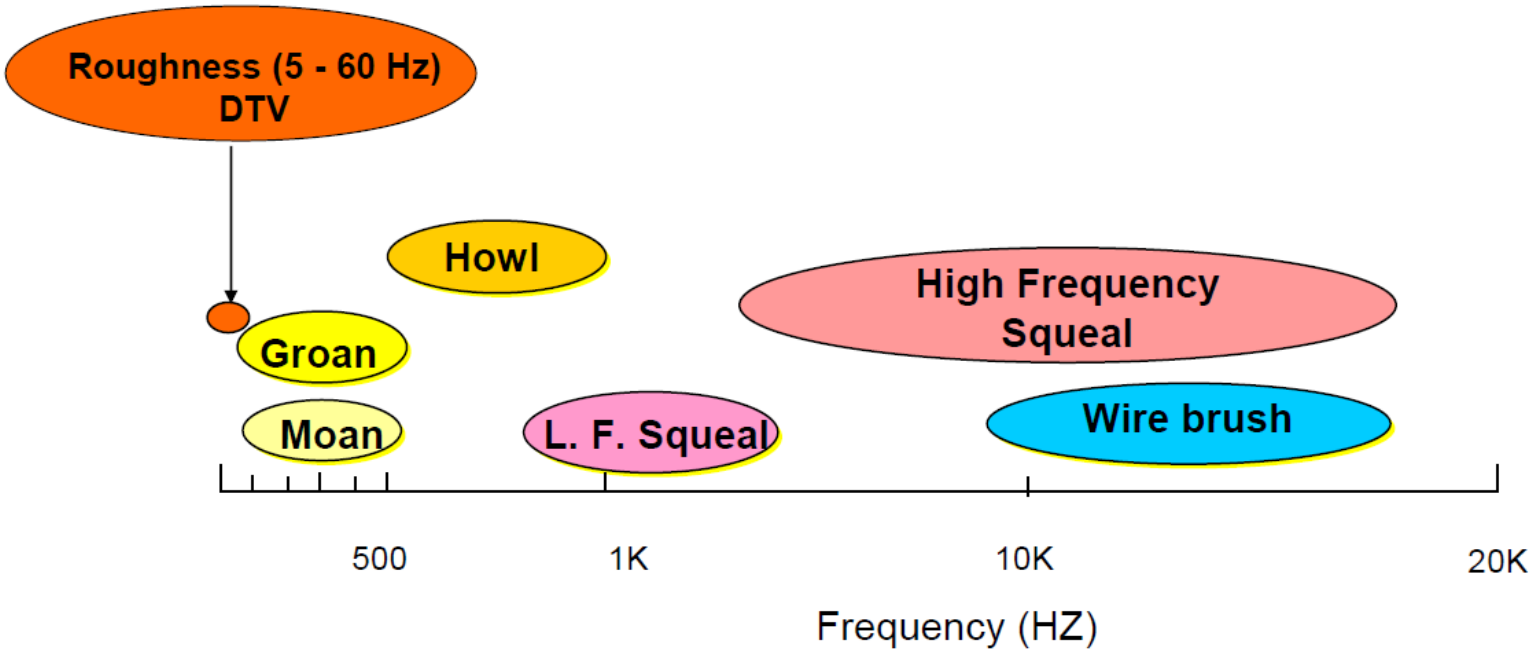
Contents

Brake noise

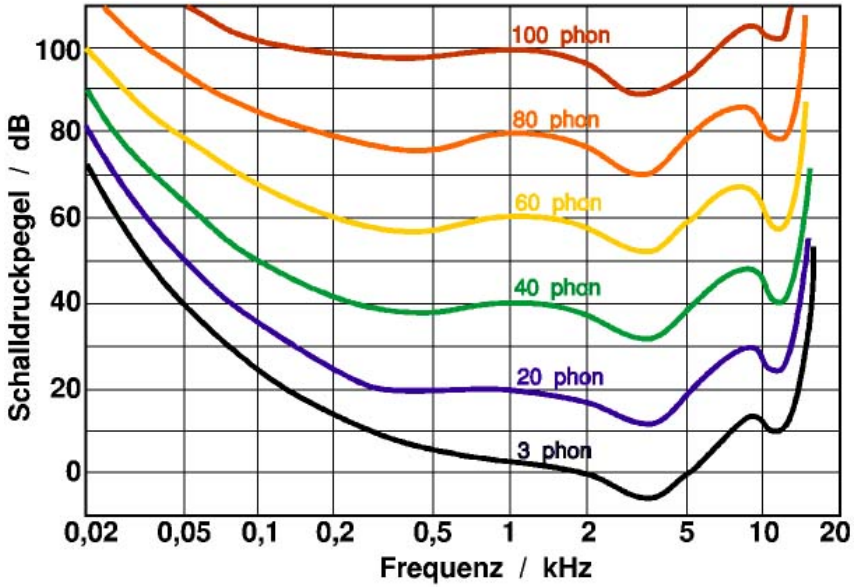
Different noises receive different names: squeal, moan, groan…



Source: LIU, W., PFEIFER, J.L., Introduction to Brake Noise & Vibration, Honeywell Friction Materials, 2003.

Brake noise

Brake noise is a problem because it affects the **quality perception the final customer has** on the car.

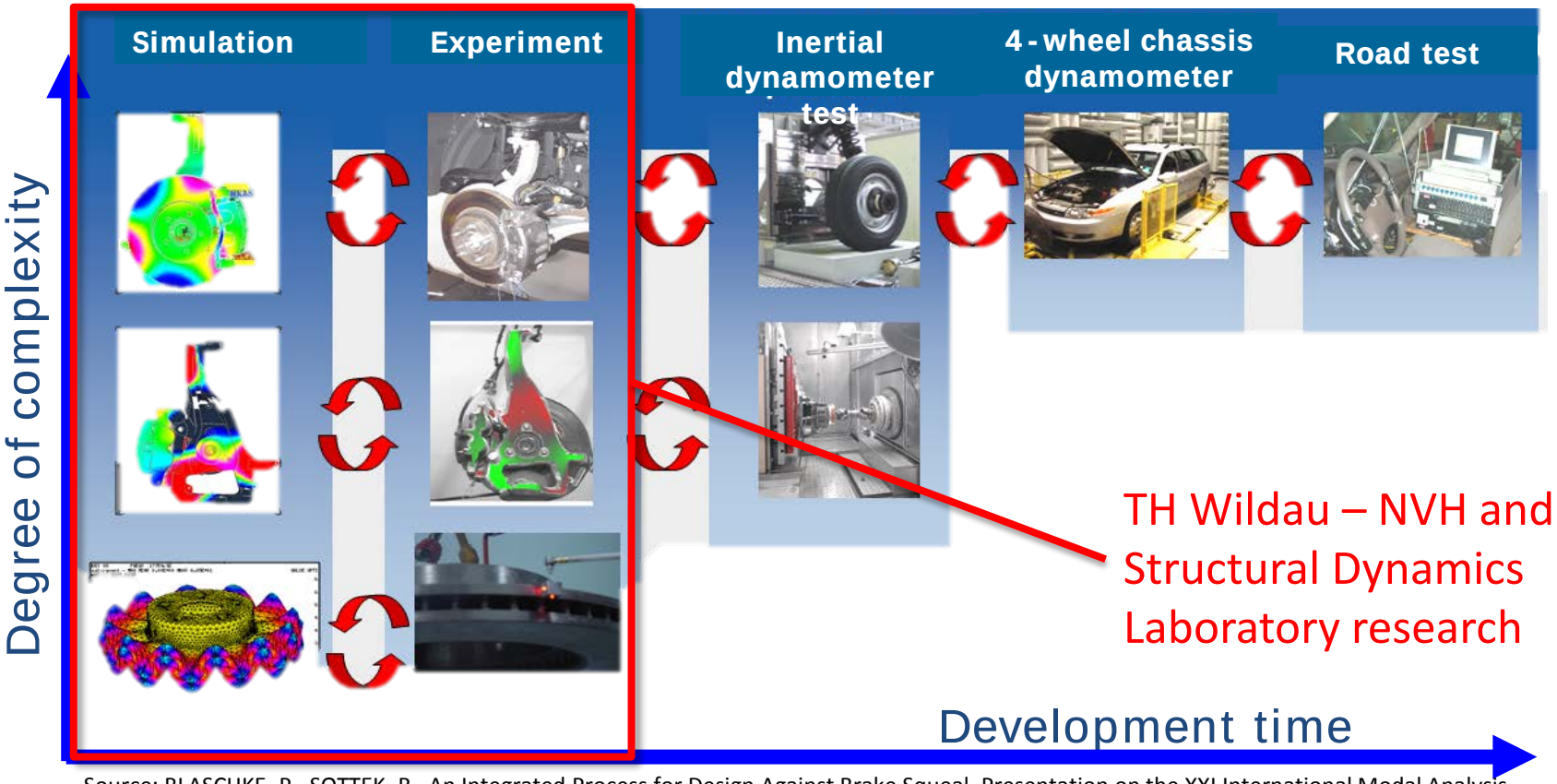


Isophonic curves

This is why the **Noise, Vibration and Harshness** industry has worked for decades trying to solve these problems.

Noise, Vibration and Harshness (NVH)

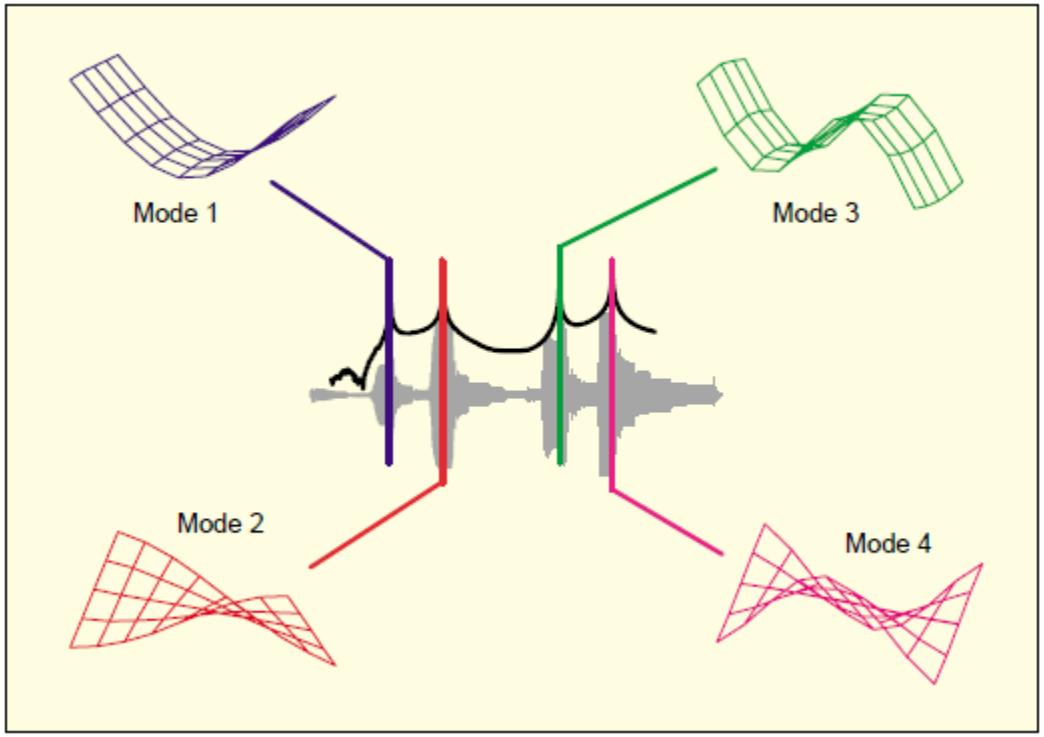
Is the study of vibration and noise in vehicles. The measurement is done by analytical tools and also by jury evaluation.



Source: BLASCHKE, P., SOTTEK, R., An Integrated Process for Design Against Brake Squeal, Presentation on the XXI International Modal Analysis Conference, Kissimee, FL, USA, February 2003.

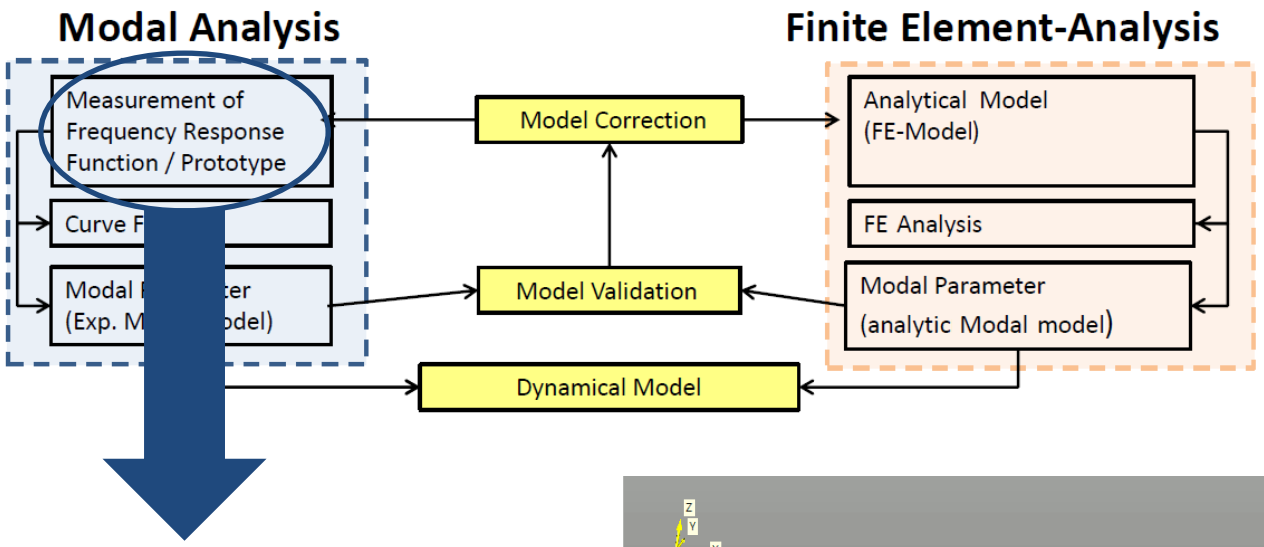
Experimental Modal Analysis

Experimental Modal Analysis is one of the techniques that allows us to know the resonant modes of a structure.

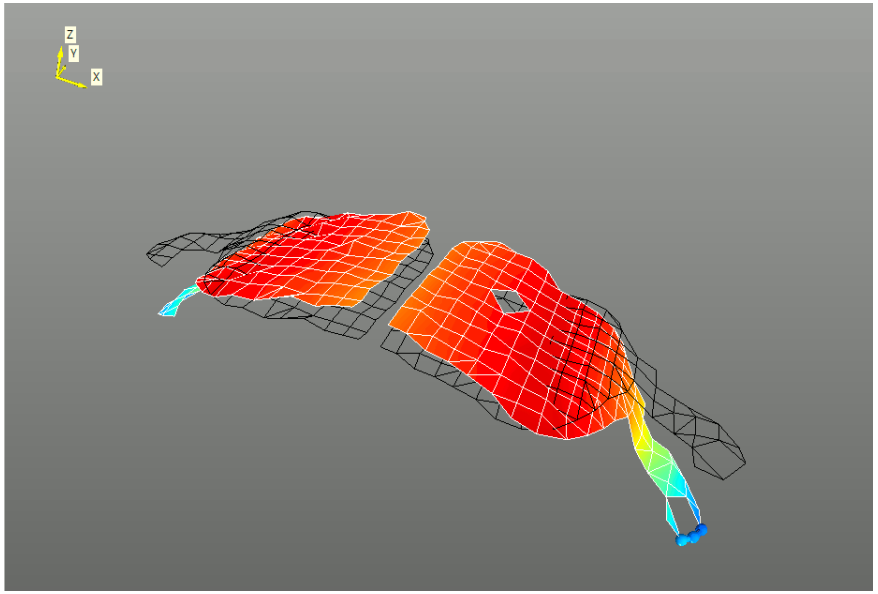


Source: Avitabile, P., Experimental Modal Analysis. A Simple, Non-Mathematical Presentation, 2001.

Experimental Modal Analysis

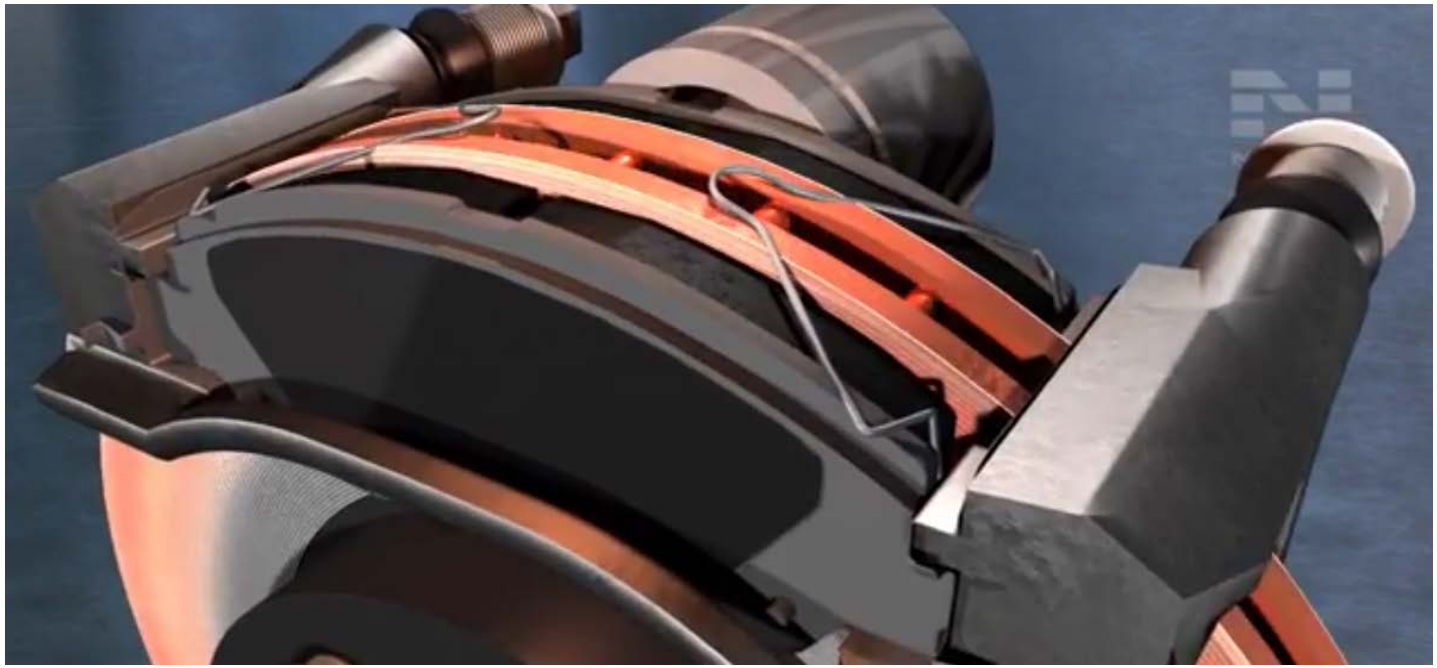


Measurements are typically made with the structure on free-free conditions.



Experimental Modal Analysis

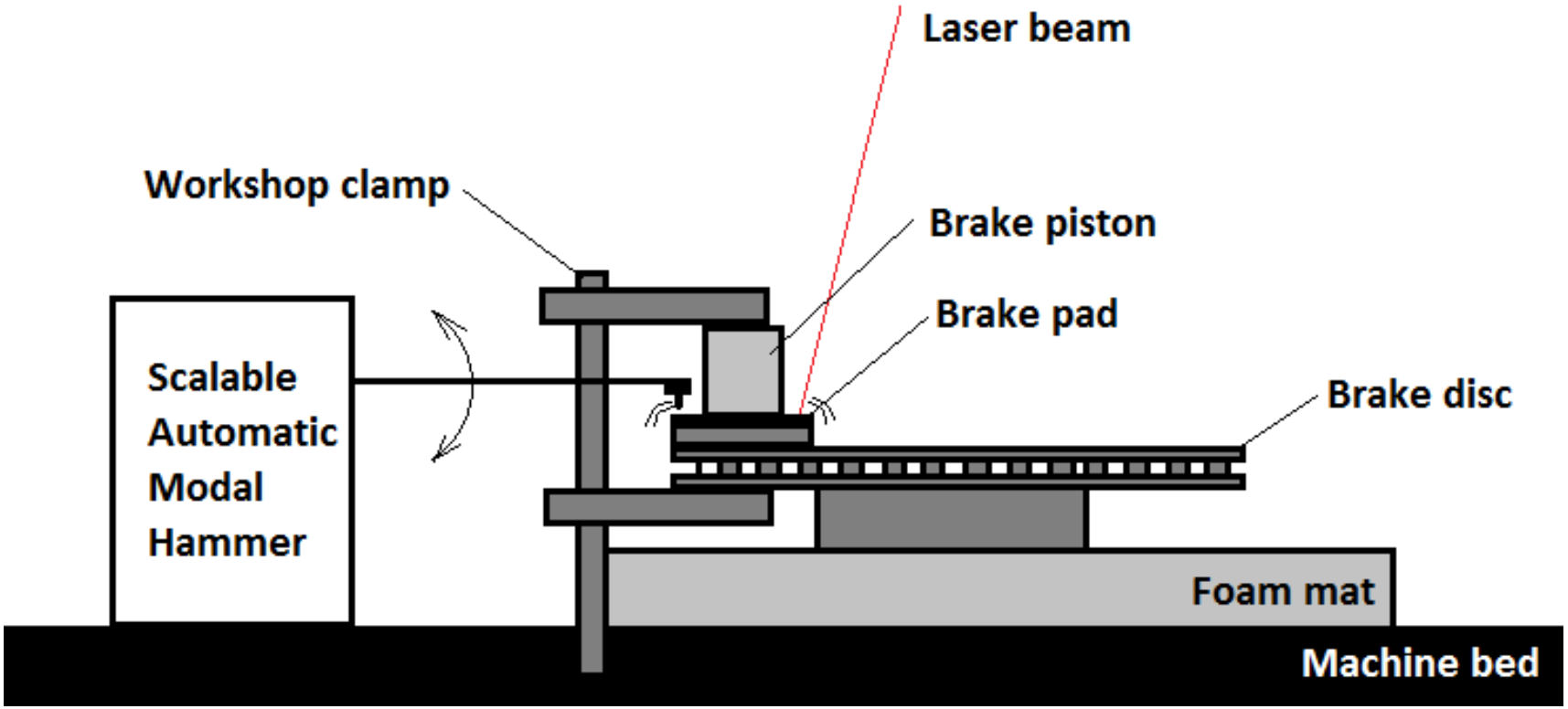
But on a braking event, brake pads are not precisely under free-free conditions...



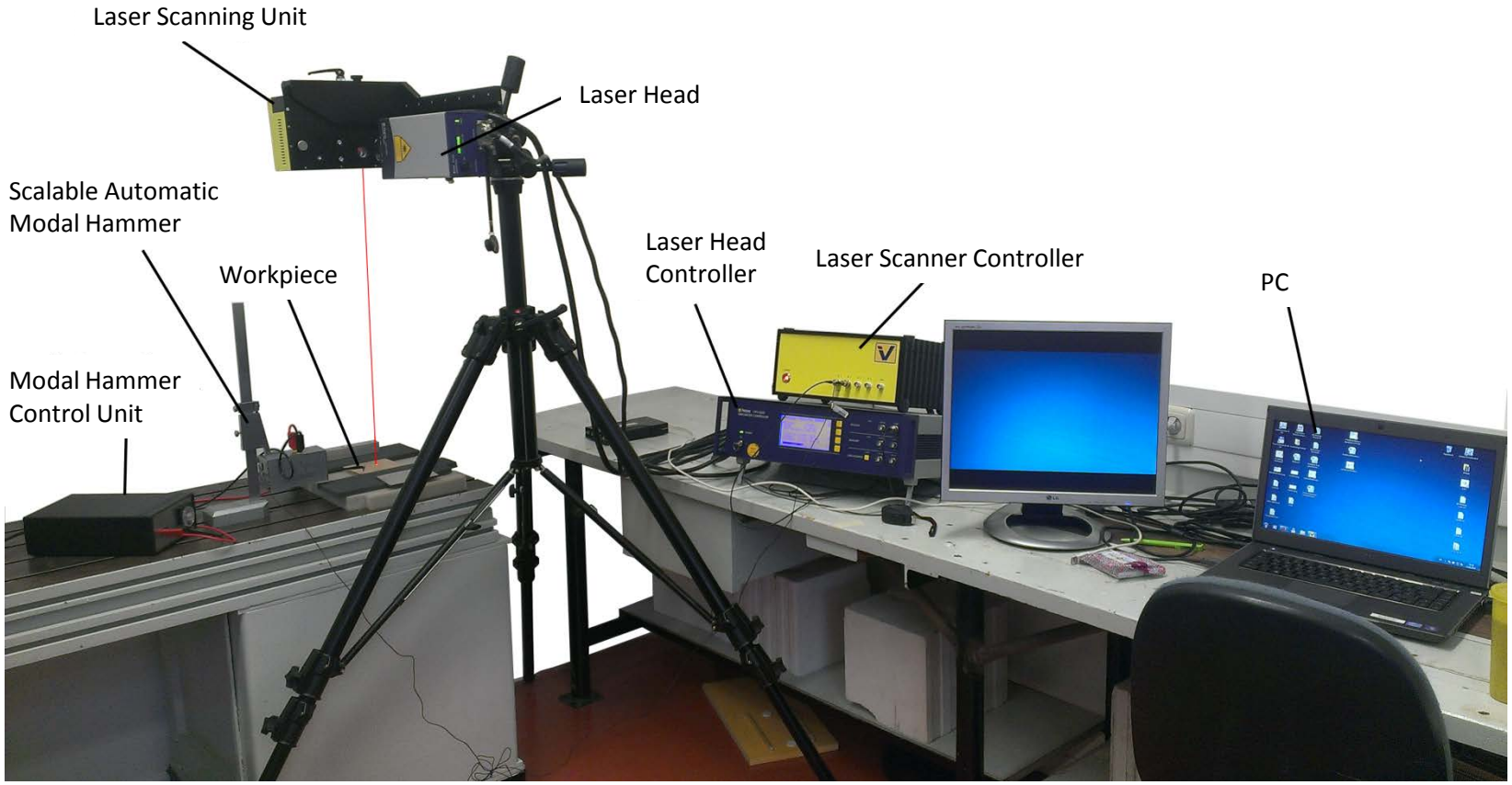
Source: NUCAP – Piston Cushion 2014 Video

The modal parameters of all components change during braking.

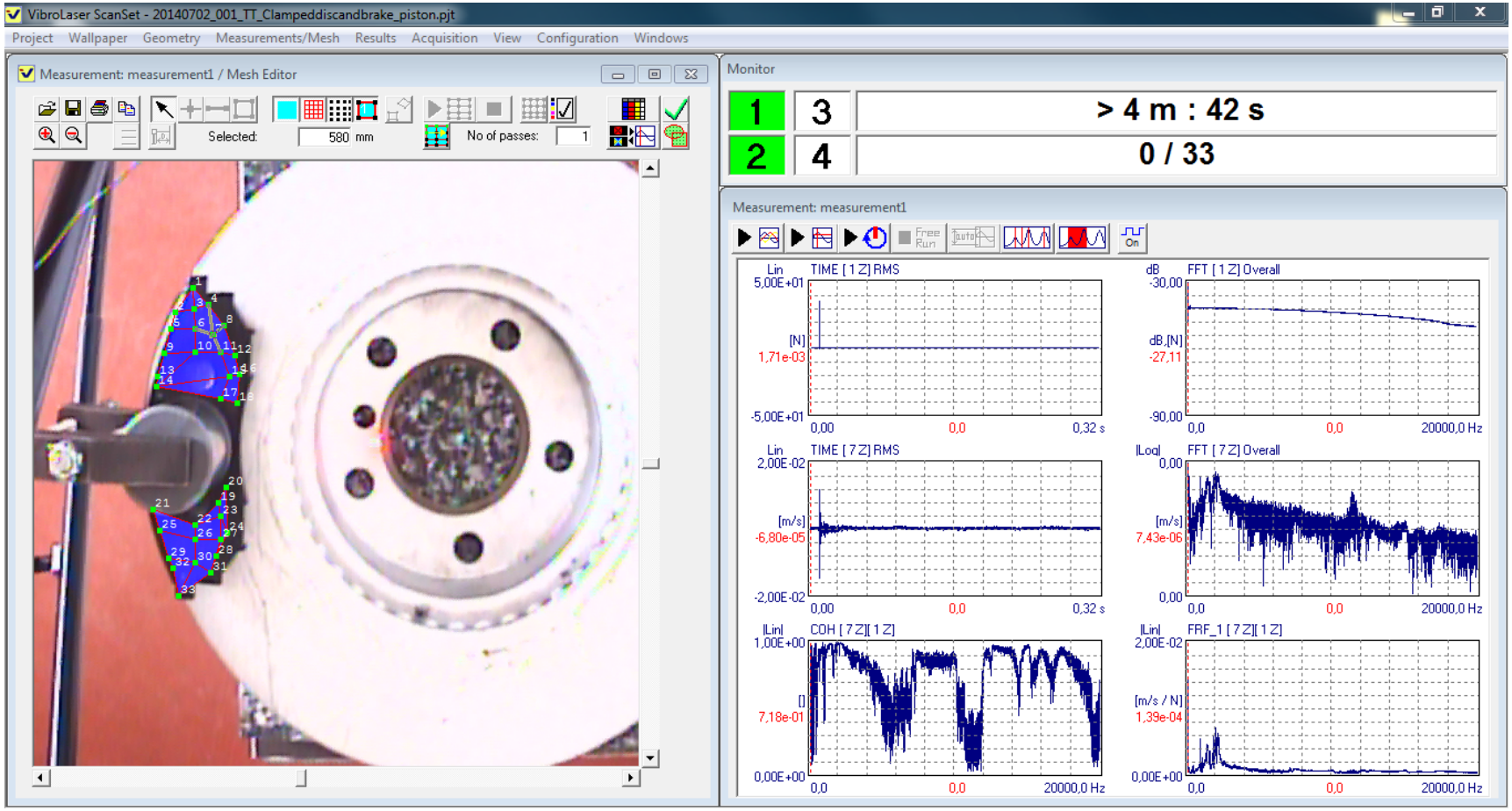
Proof of Concept



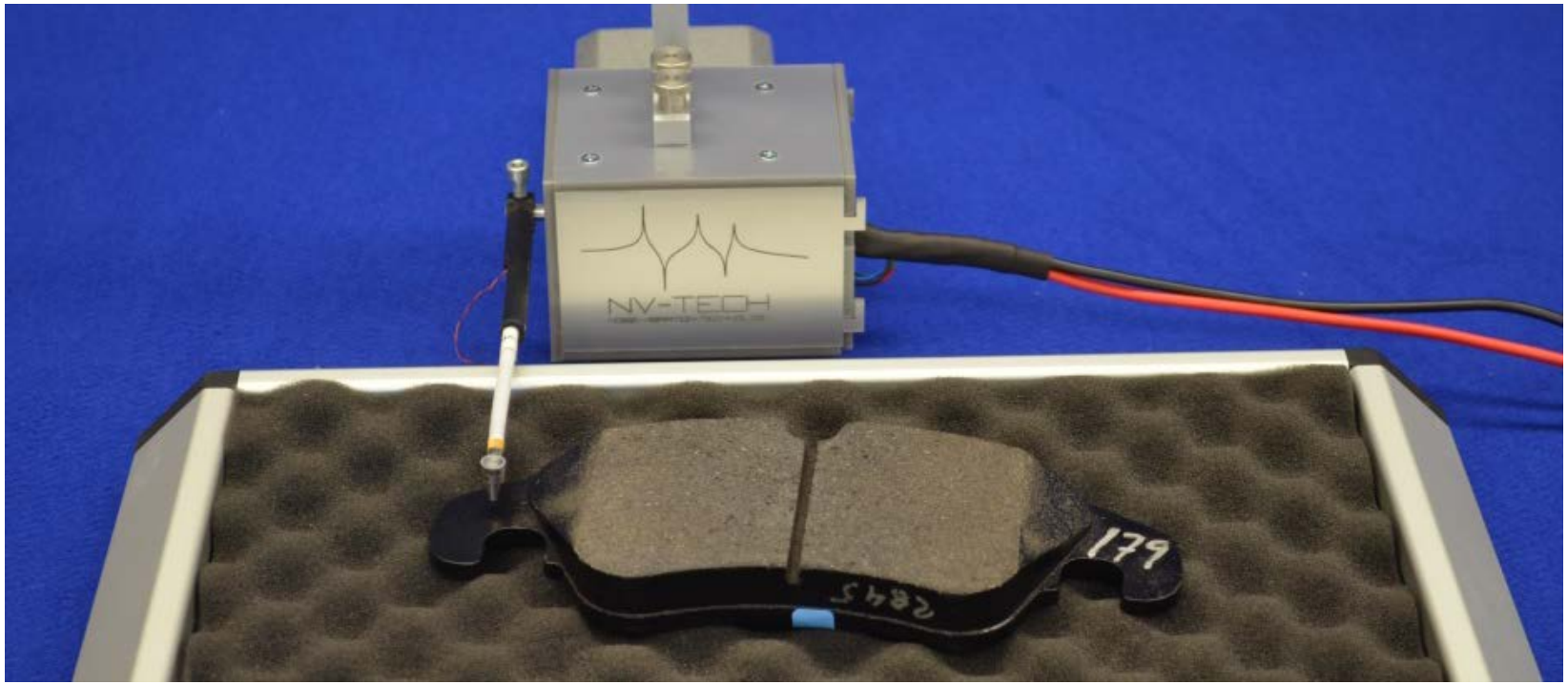
Proof of Concept: Methodology



Proof of Concept: Methodology



Proof of Concept:
Scalable Automatic Modal Hammer



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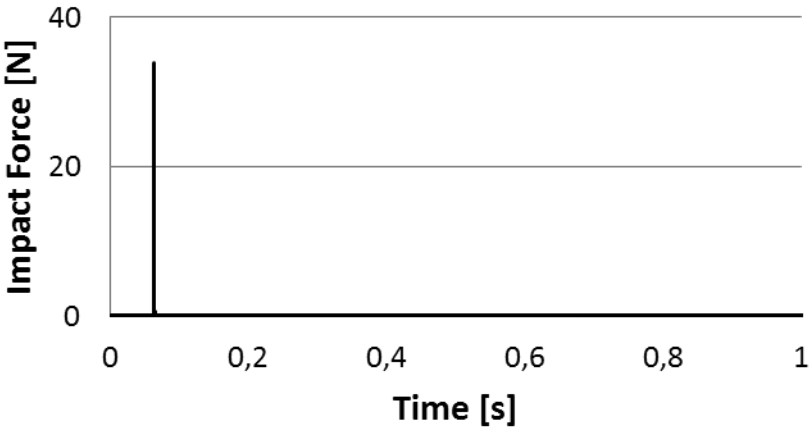
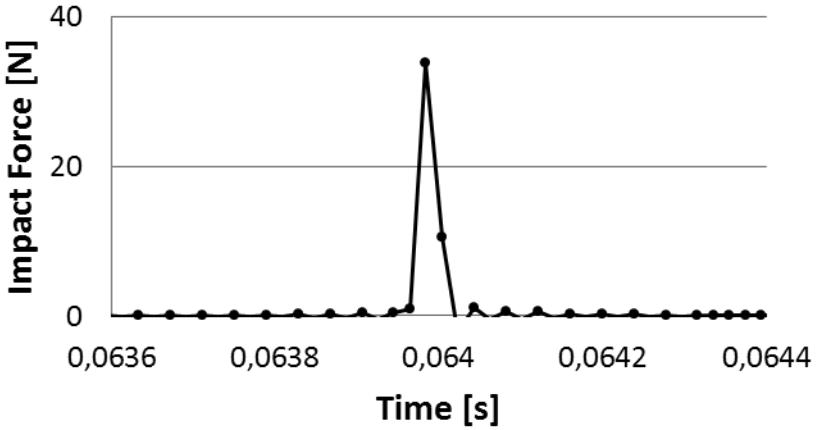
Scalable Automatic Modal Hammer

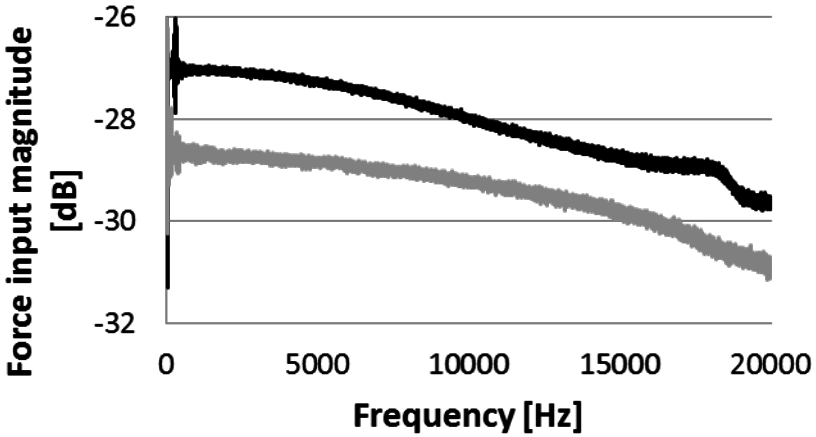


Impact – time signal

Proof of Concept:
Scalable Automatic Modal Hammer



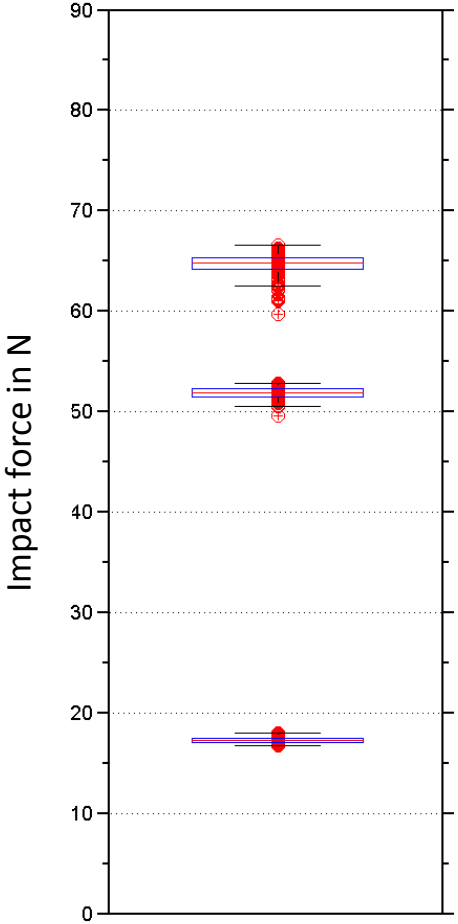
Impact - time signal - zoom



Impact - autospectrum signal

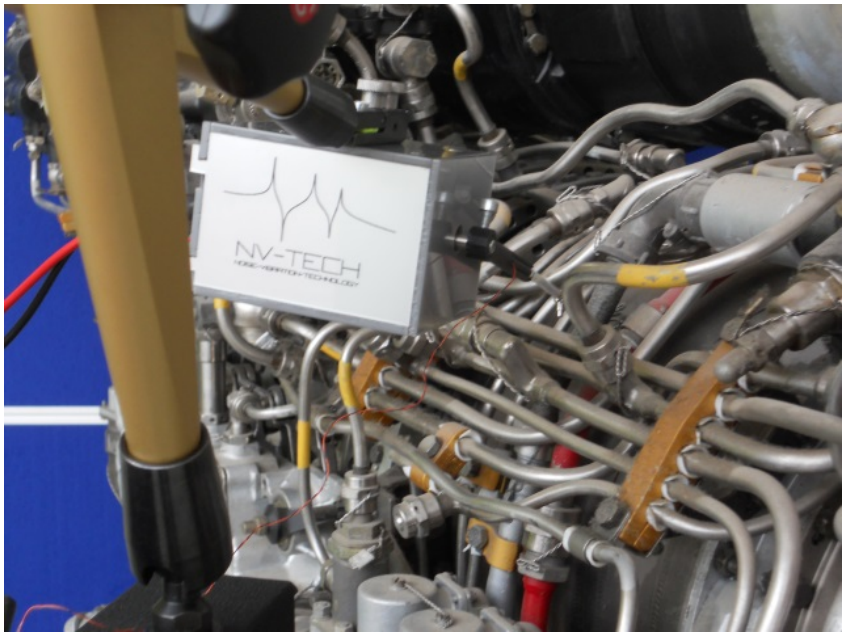
In grey, autospectrum signal of a magnet-driven automatic hammer

Proof of Concept:
Scalable Automatic Modal Hammer

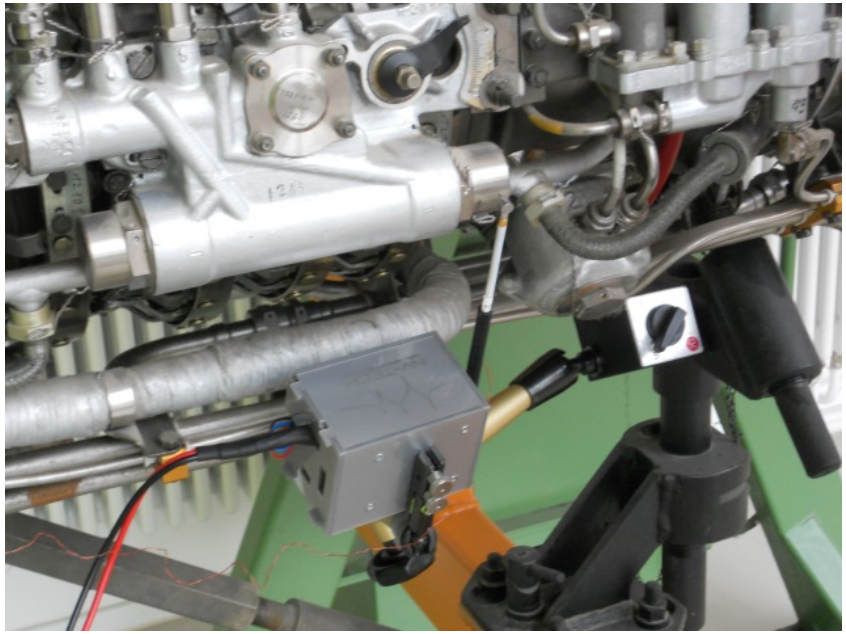


Repeatability test, applied to a brake pad backing plate.

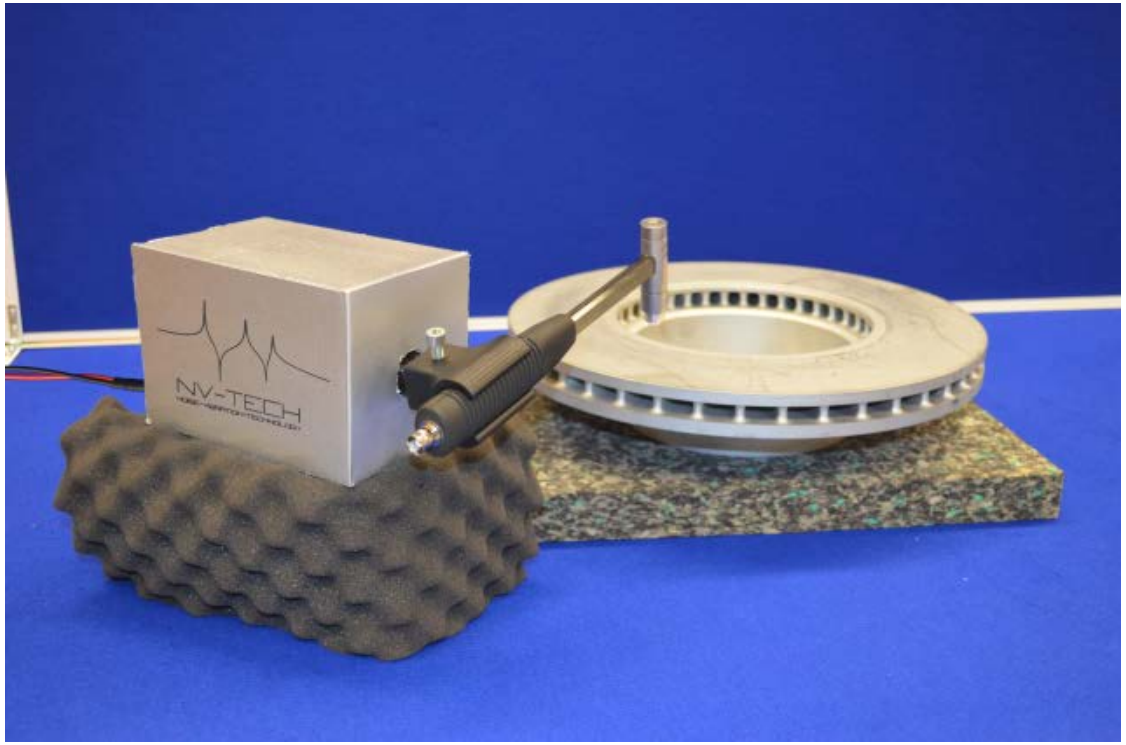
Proof of Concept:
Scalable Automatic Modal Hammer



Application examples
with magnetic arm



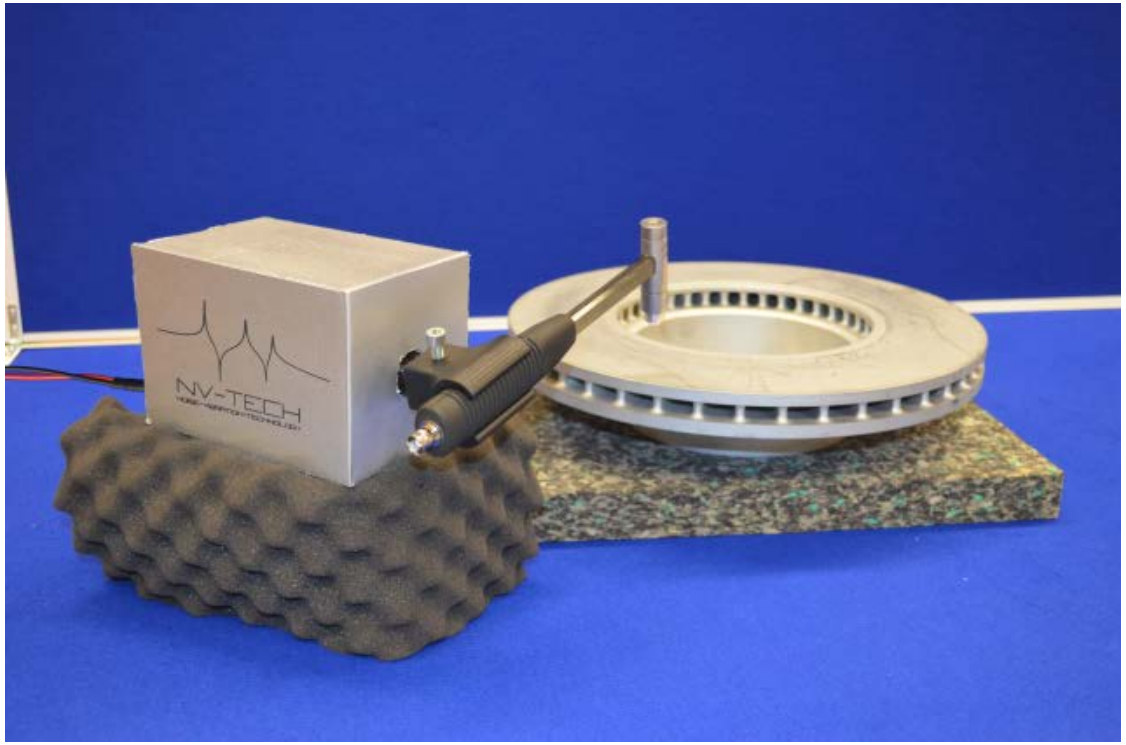
Proof of Concept:
Scalable Automatic Modal Hammer



Heavier structures?

Larger hammer!

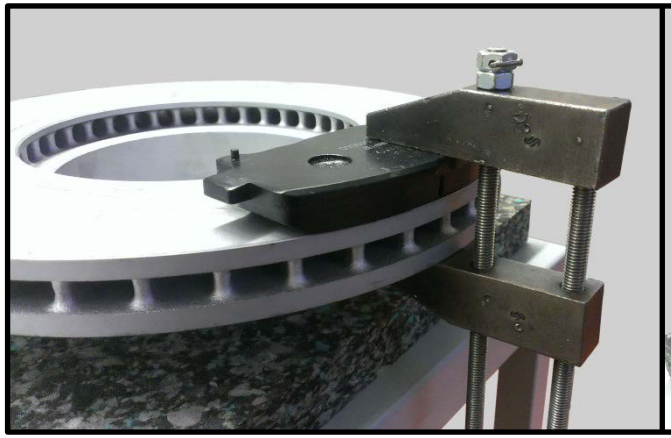
Proof of Concept:
Scalable Automatic Modal Hammer



Heavier structures?

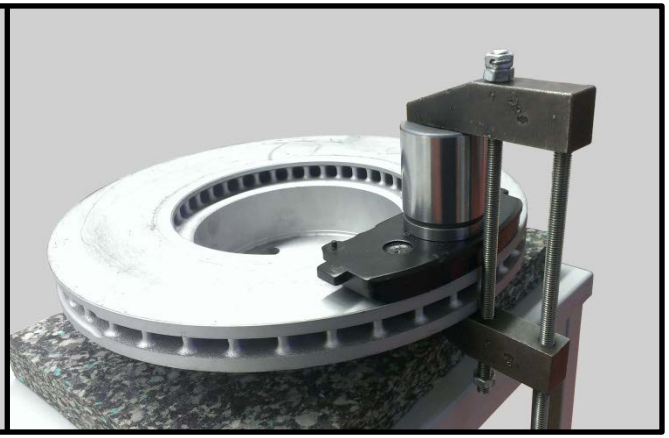
… but narrower excitation band!

Proof of Concept: Assemblies



Pad/disc assembly

- Weak clamping force
- High clamping force

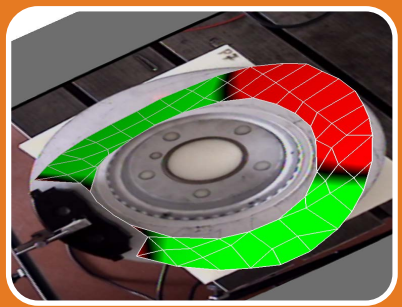


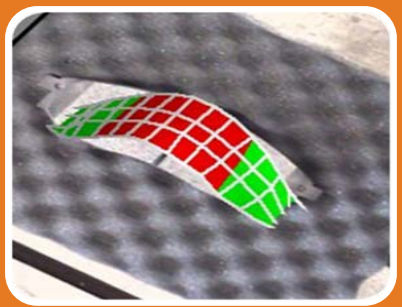
Piston/pad/disc assembly

- Weak clamping force
- High clamping force

Proof of Concept: Experiments

Pad A





Disc

- Free-free condition

Pad

- Free-free condition
- Grounded condition

Pad/disc

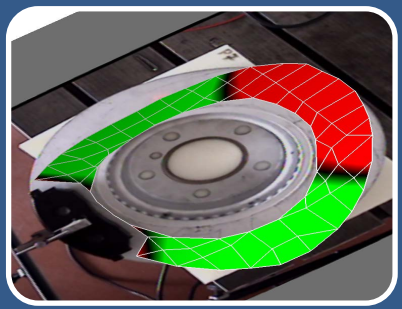
- Weak clamping force
- High clamping force

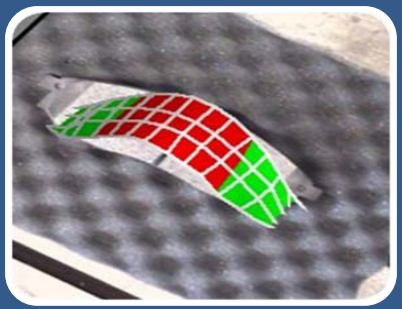
Piston/pad/-disc

- Weak clamping force
- High clamping force

Proof of Concept: Experiments

Pad B





Disc

- Free-free condition

Pad

- Free-free condition
- Grounded condition

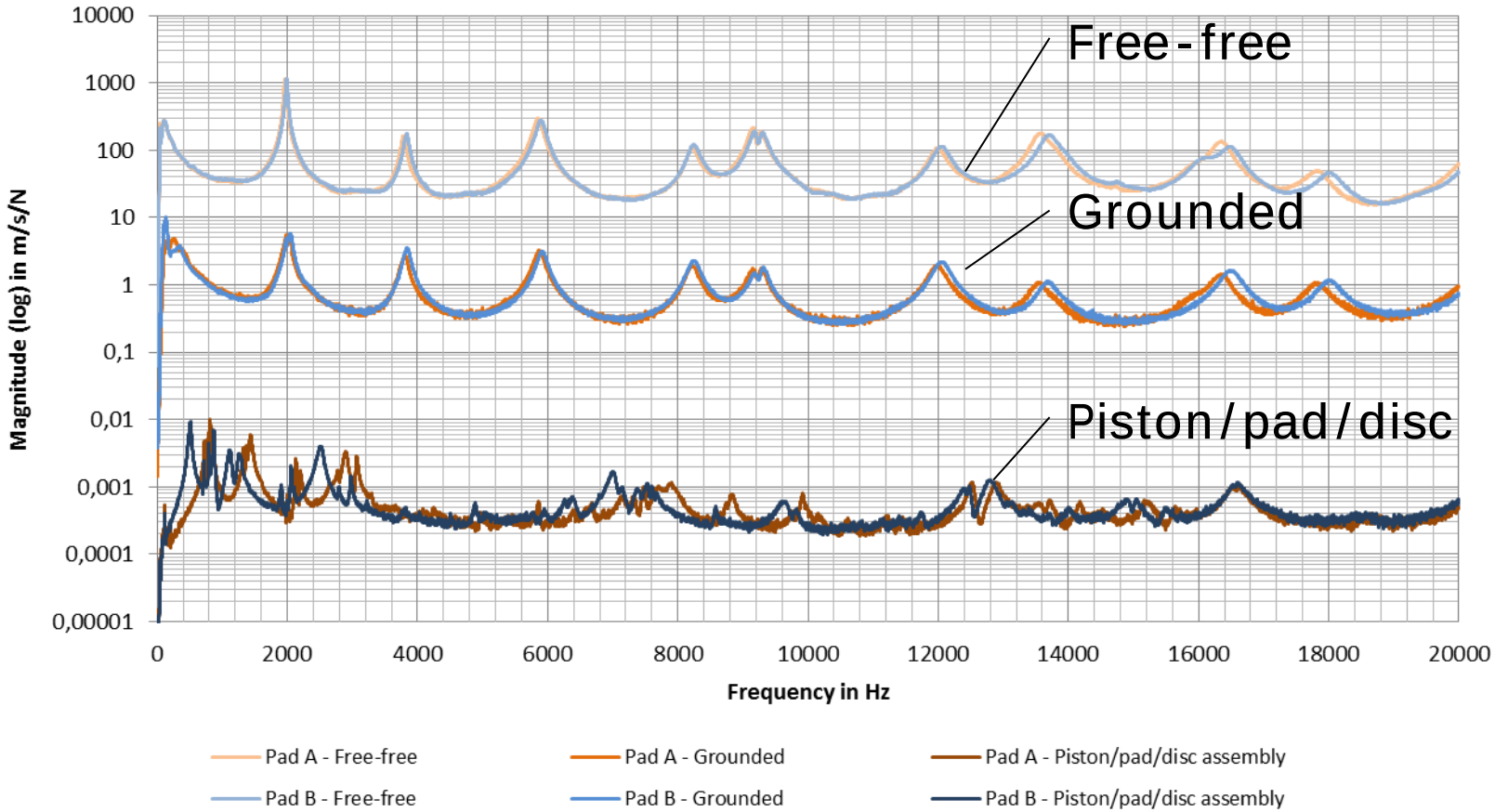
Pad/disc

- Weak clamping force
- High clamping force

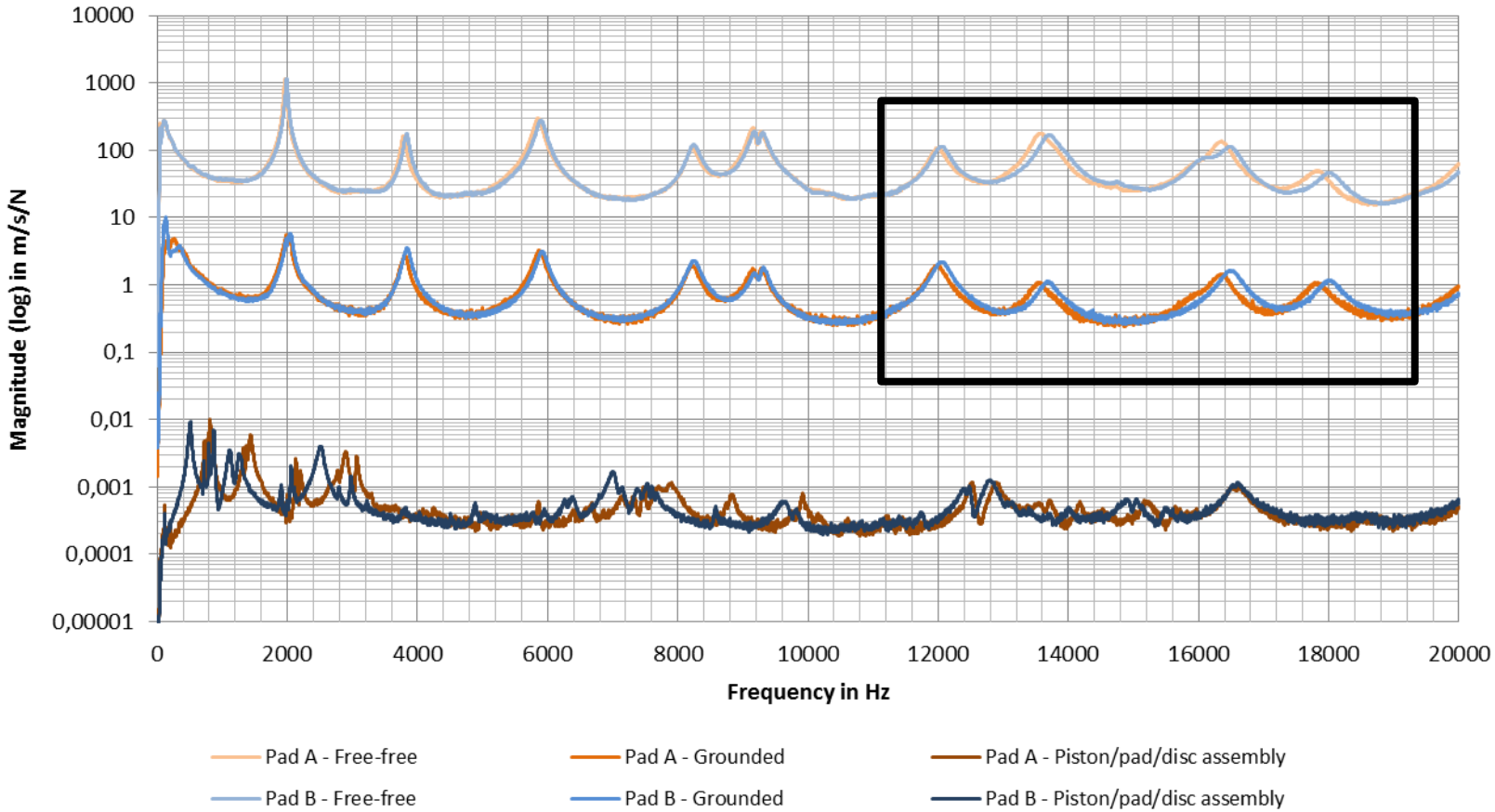
Piston/pad/-disc

- Weak clamping force
- High clamping force

Study Results: Direct Comparison of FRF Additions

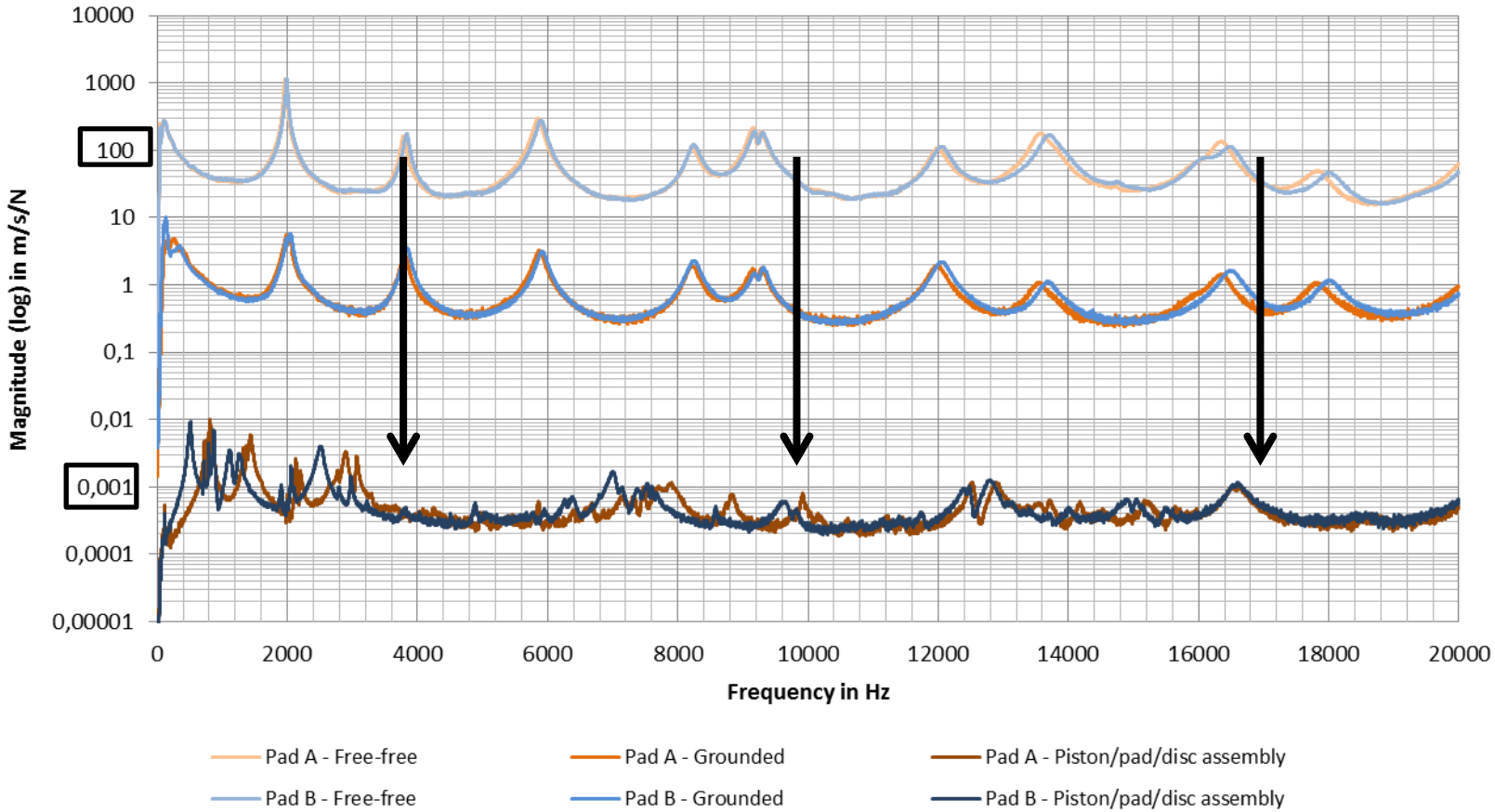


Study Results: Direct Comparison of FRF Additions



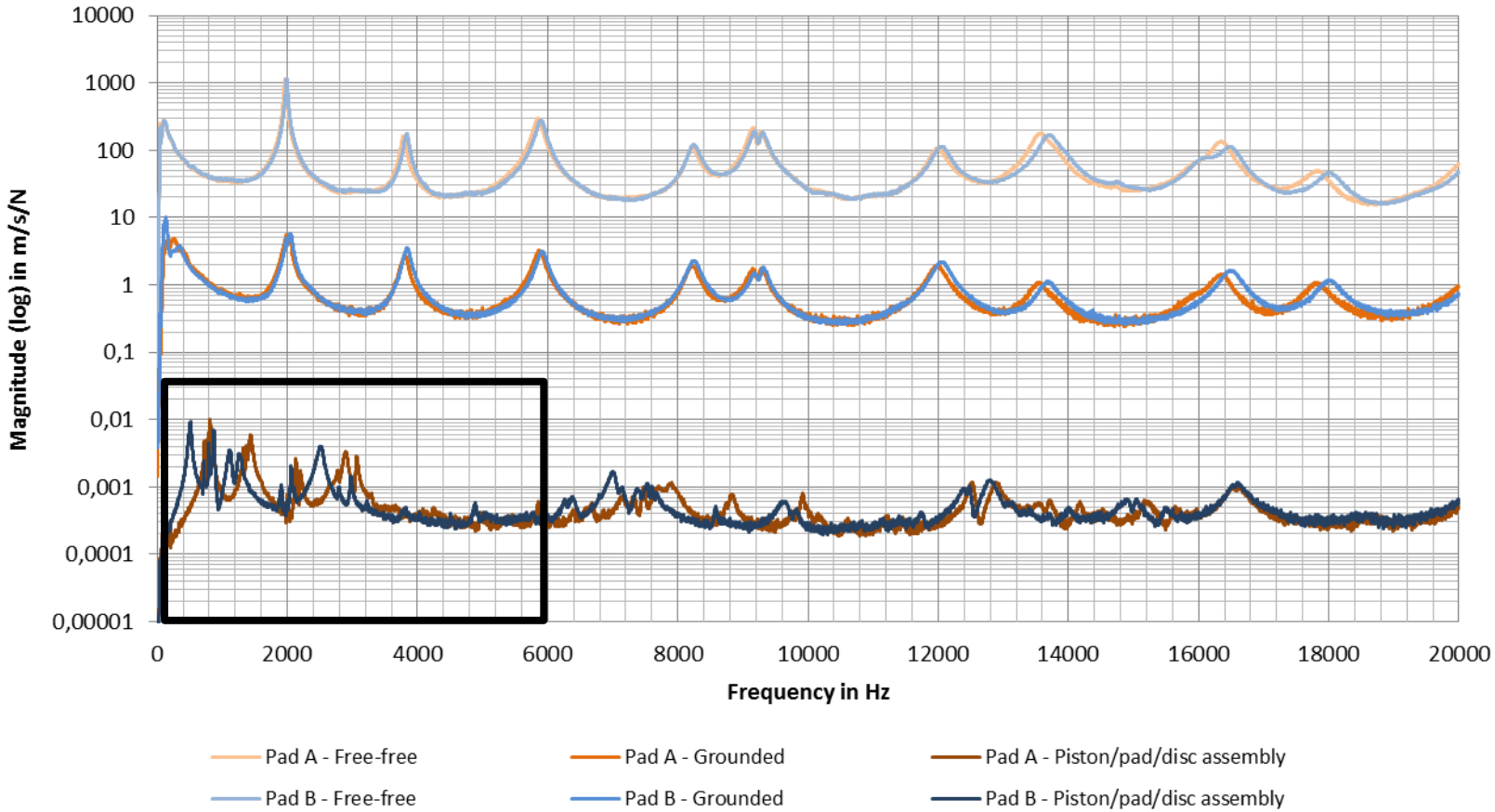
Frequency shifts between pads at higher frequencies → different dynamic properties.
Caused by different compressibility value?

Study Results: Direct Comparison of FRF Additions



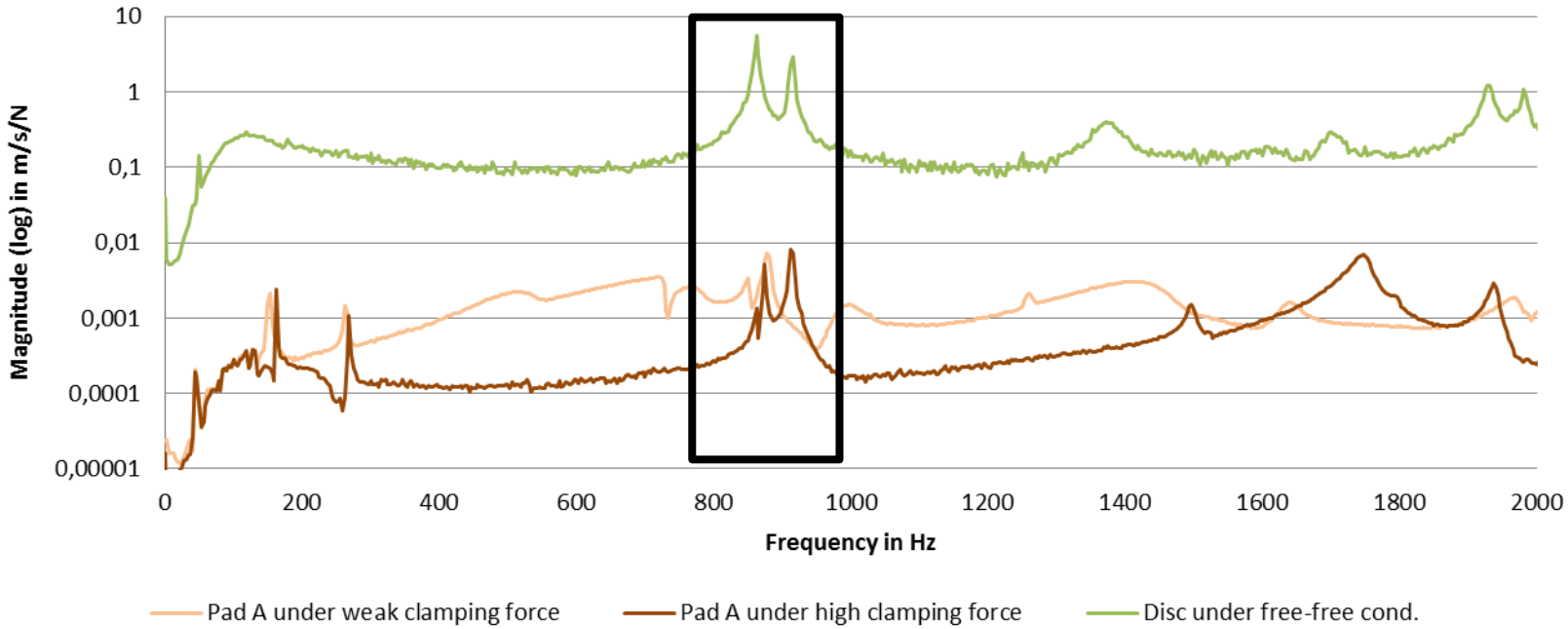
Weaker vibration → 5 orders of magnitude less.
Signal-to-noise ratio decreases, due to the weak vibration amplitude.

Study Results: Direct Comparison of FRF Additions



Prominent but erratic peaks on the low frequency range.

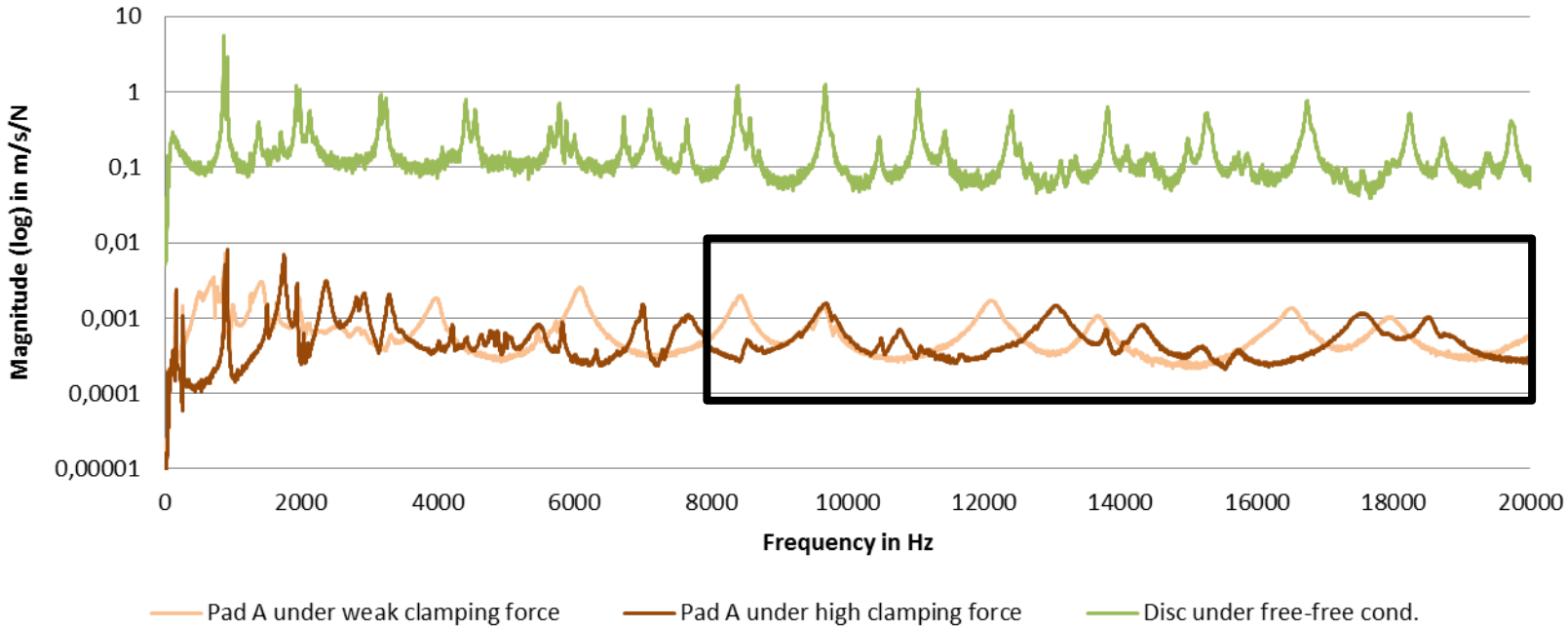
Study Results: Low Freq. Range



The first two modes of the brake disc are coincident with the first two peaks on the FRFs additions.

Both components seem to be affecting each other in terms of mass, stiffness and damping.

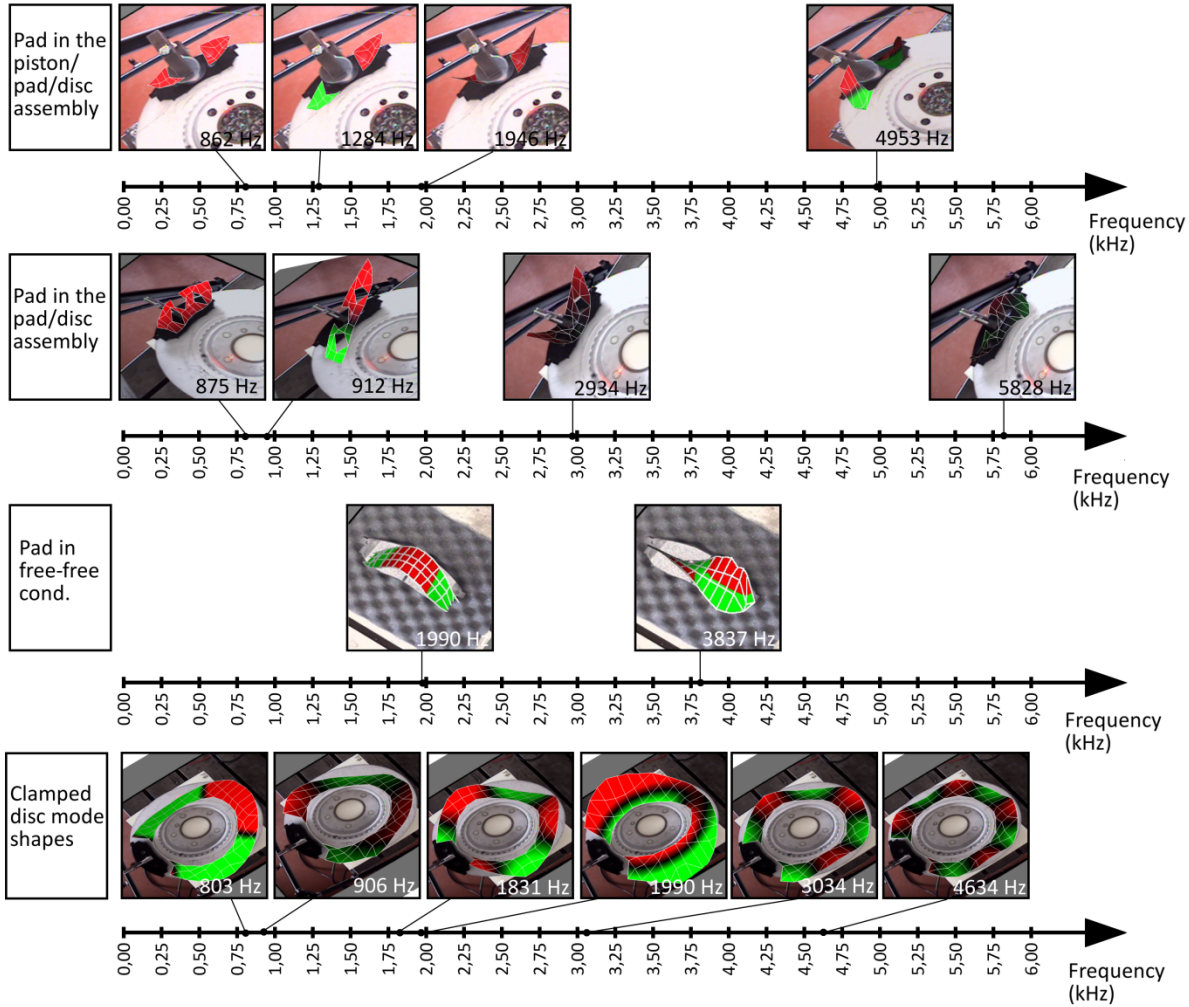
Study Results: High Freq. Range



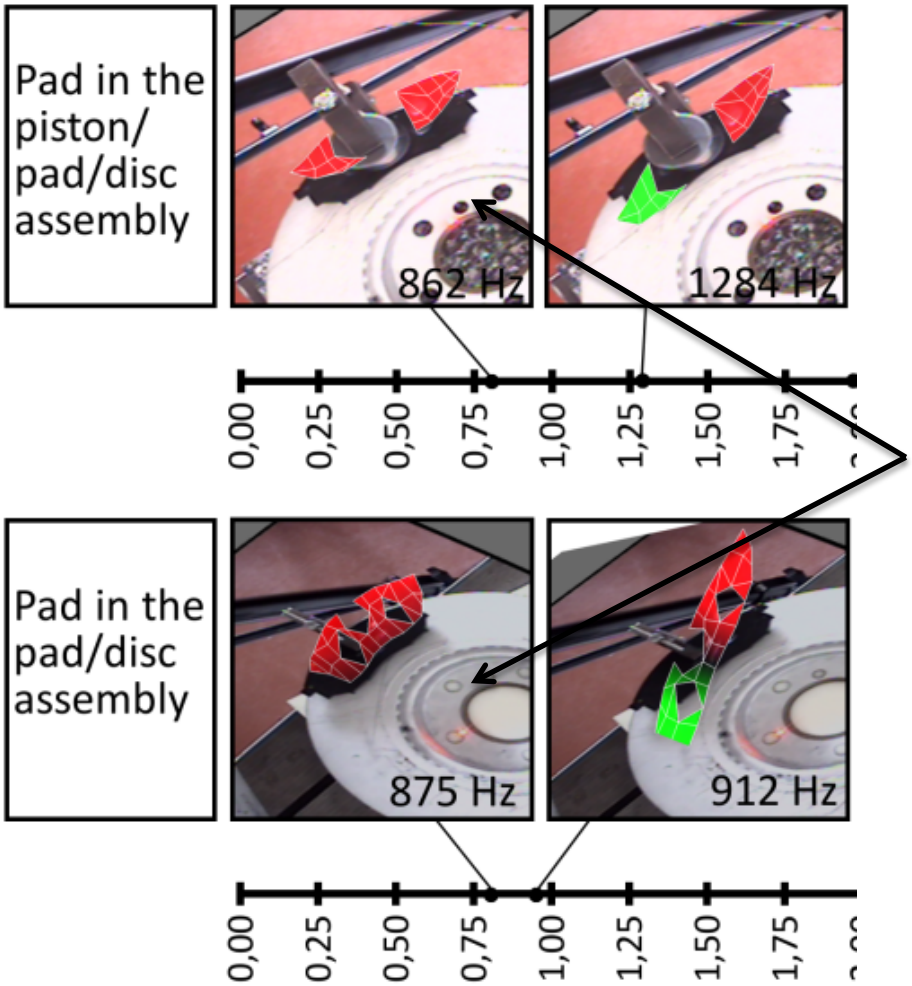
The high frequency range is less erratic and the peaks are not coincident anymore.

Modal parameters become easier to extract.

Study Results: Mode Shapes Comparison



Study Results: Mode Shapes Comparison

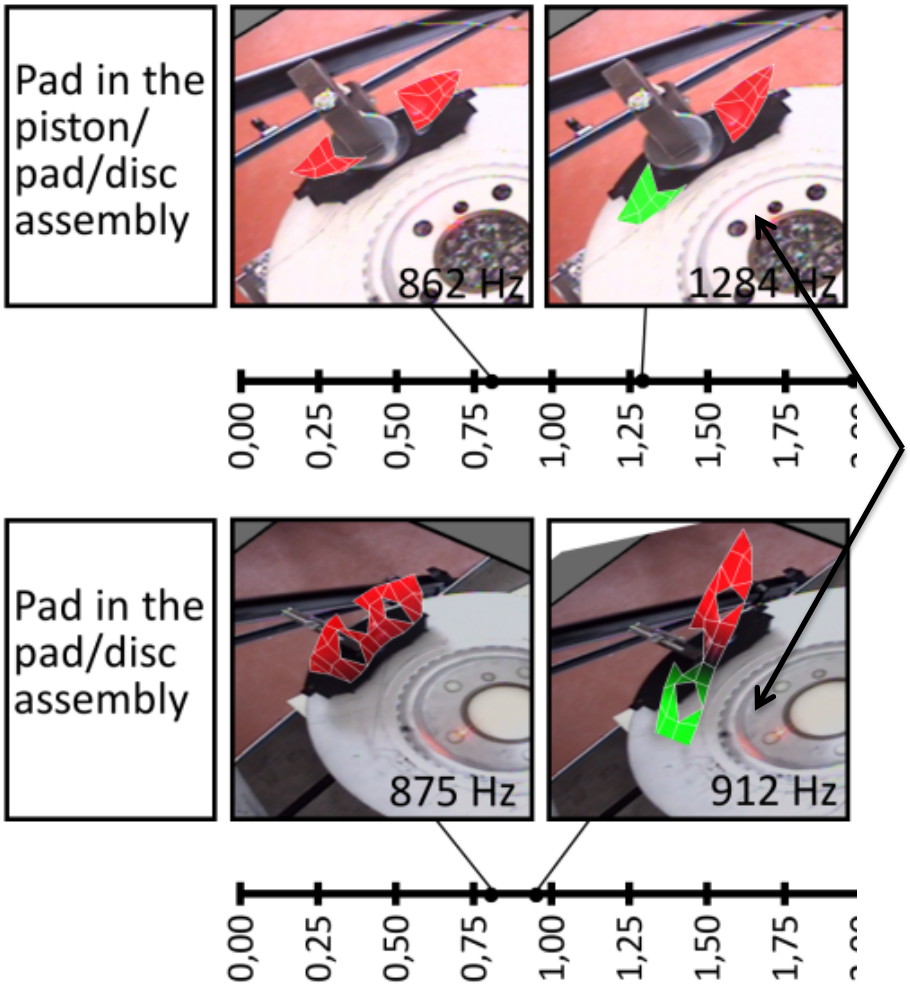


<u>Up-and-down Shapes</u>

It is suspected that they are caused by the brake disc first mode, which is transmitted onto the pad.

In reality, the whole assembly is vibrating.

Study Results: Mode Shapes Comparison



<u>"Flip-flop" Shapes</u>

Further tests without disc have shown that they are inherent to the pad under compression.

Conclusions

- ✓ The feasibility of the proposed proof of concept has been evaluated.
- ✓ Mode shapes up to 6 kHz have been successfully extracted. Data acquisition has been done in a quasi-automatic approach.
- ✓ The vibration of the brake disc where the assemblies are mounted has an influence on the low-frequency results.
- ✓ The dynamic differences between pads seem to increase when the pads are analyzed under compression loads.

Further Work

The proposed setup still has some drawbacks and practical limitations. Several improvements to the have been proposed to this research:

- ✓ Brake pads testing without brake disc in order to remove the low-frequency distorsions. As a result, the compression load would be applied onto the pads in a similar manner as a pad comperessibility test stand does.
- ✓ Quantifiable compression load, by means of a force sensor.
- ✓ Results‘ correlation with FEA models.
- ✓ Modal damping should be evaluated on next studies.

Thanks for your attention!

Prof. Dr. Peter G. Blaschke

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