Dynamic Boundary Samples for Robust NVH Design Using Smart Simulation Methods

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Abstract

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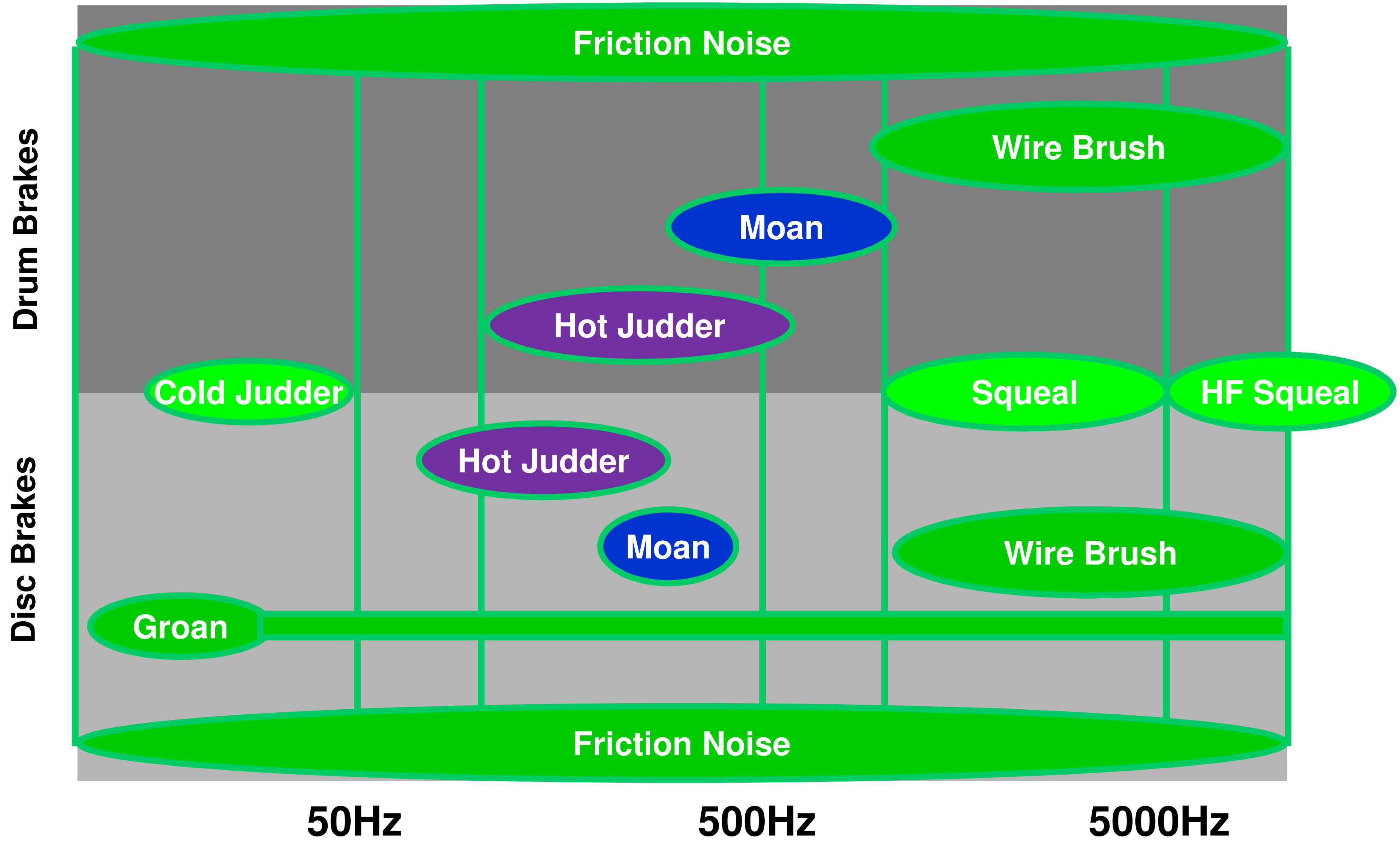
- The current market situation in for wheel brakes requires a high performance quality in regard to NVH, not only in the development phase, also later in the field. In order to avoid warranty issues there is a need to design and test the brake design for NVH robustness purpose. The major dynamic variance in a brake system is usually the rotor variance and the scatter of the lining; therefore TRW is using a standardized robustness test approach in the NVH process to validate the brake NVH robustness by rotor and pad variations. Here based on existing parts close to production start minimum and maximum frequency parts, respectively minimum and maximum compressibility linings are selected and tested. For the casted brake parts, carrier and housing, the expected frequency drifts are expected by maximum 3% over time based on measurements over production life of casting tools and production cycle. Supplier changes can cause a shift in the eigenfrequencies as well, but all changes will be within the limit of the drawing tolerances. The challenge is now to identify the possible frequency scatter based on drawing tolerances in order to limit the frequency scatter by an intelligent adjustment of the tolerances and to define exact geometries for boundary samples, representing minimum and maximum eigenfrequencies for specific eigenmodes. This will allow TRW to test the extreme frequency situations, possible based on the drawing limits. TRW developed a simulation approach, which allows the identification of the frequency limits for all possible geometrical situations. With sensitivity studies the parameter importance is evaluated and for the relevant frequencies geometrical optimizations are performed to define the physical boundary samples. For NVH robustness tests these geometries can be produced and validated.

Brake Noise Types



Motivation

- **NVH field complaints and warranty costs**
- **Permanently increasing customer requirements and targets**

- **CAE helps to mitigate NVH risk by**
  - Robustness testing → Development
  - Production NVH quality control → Production

Simulation Targets

- **CAE is needed to investigate possible frequency scatter based on drawing parameters and to define dynamic boundary samples**

  → Dynamic boundary samples are parts with minimum, respectively maximum eigenfrequencies for certain eigenmodes

- **Definition of frequency scatter for production drawings**

CAE Process for NVH Boundary Samples

FEA (component modal Analysis) and correlation to test

↓

Parameterization of Finite Element Model

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Robustness / Sensitivity study and Optimization

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Redesign of FE results (CAD)

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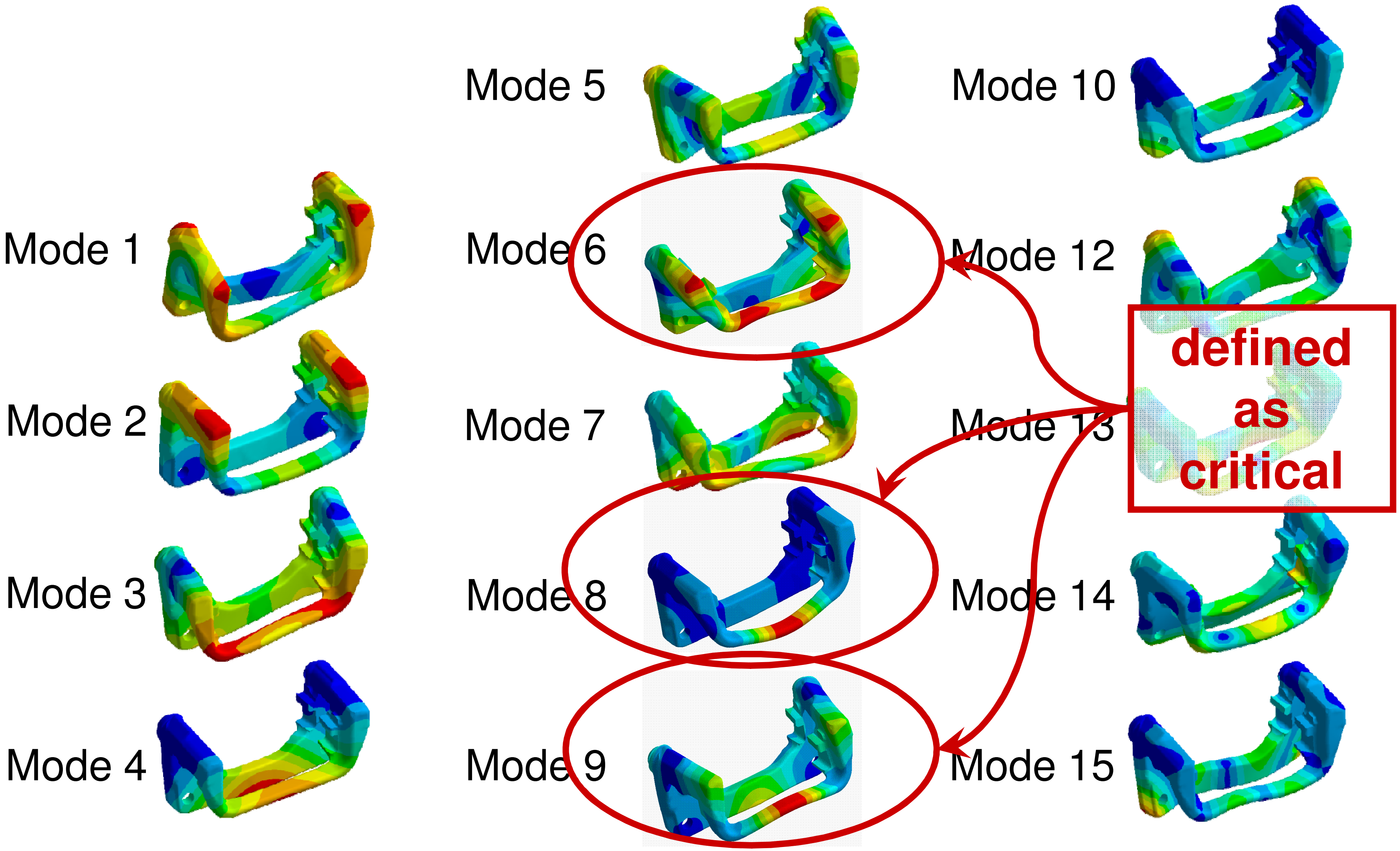
Prototyping

↓

Eigenfrequencies on Drawing

Brake Carrier Mode Shapes

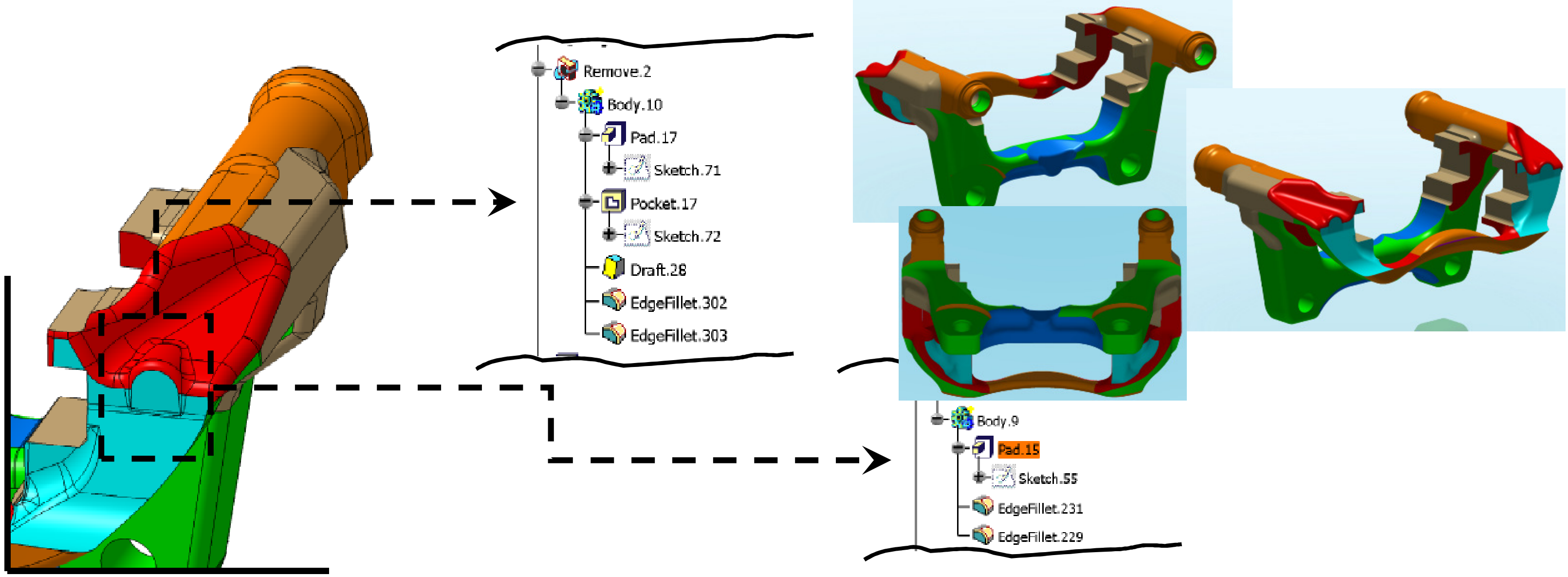


CAE parameterization Solutions

Basically two methods to parameterize the FE problem are possible

- **Parameter Setup 1**
  - Parameterization based on geometry items / CAD
- **Parameter Setup 2**
  - Parameterization based on finite element morphing handles

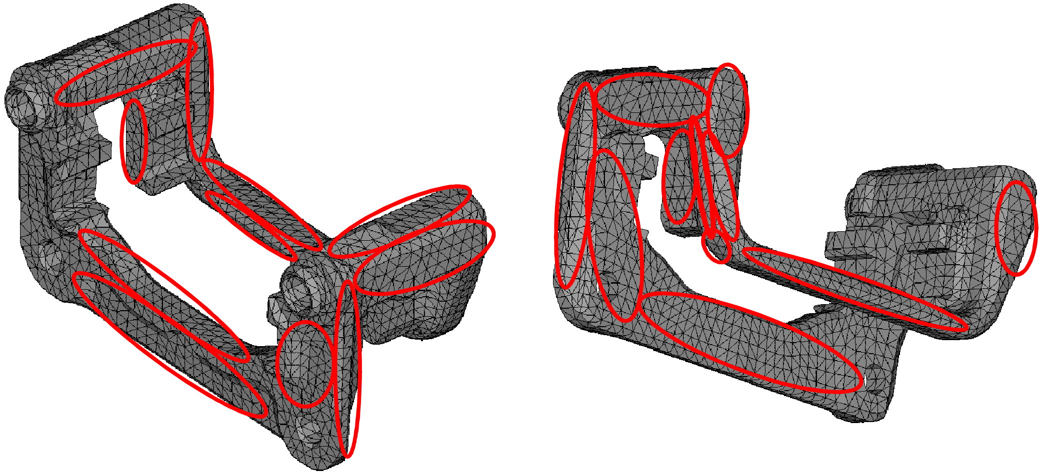
Parameter Setup 1



- Parameters in CAD → Effort for design department
- Dependencies of parameters are not allowing simple model manipulation

→ **Parameter manipulation not robust, CAD systems are often not able to calculate geometries!**

Parameter Setup 2



- Parameters = node sets
- Variation range = drawing tolerances
- Mesh morphing

→ **final geometry needs to be translated back to CAD**

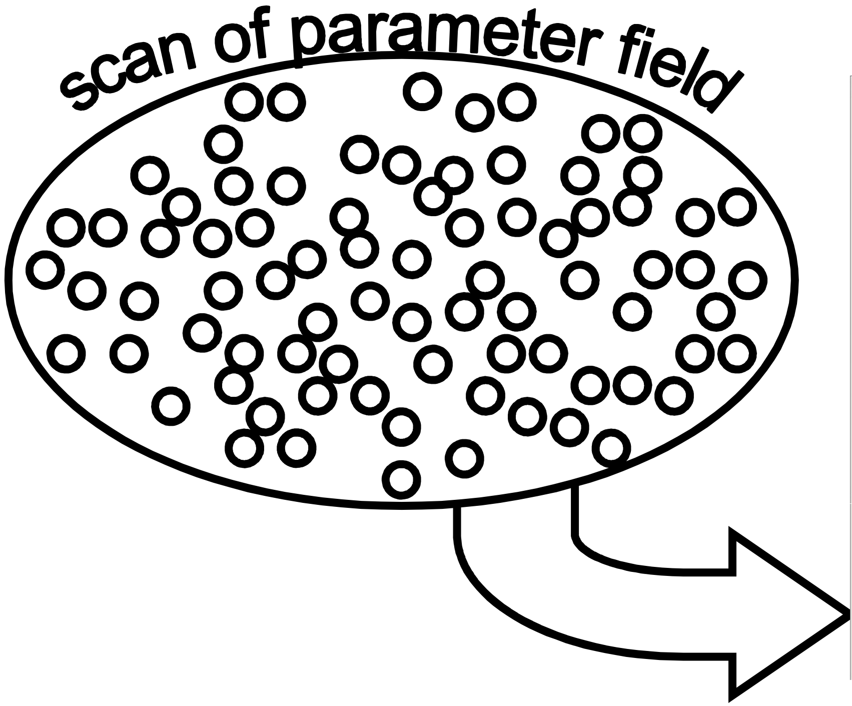
→ **Redesign!**

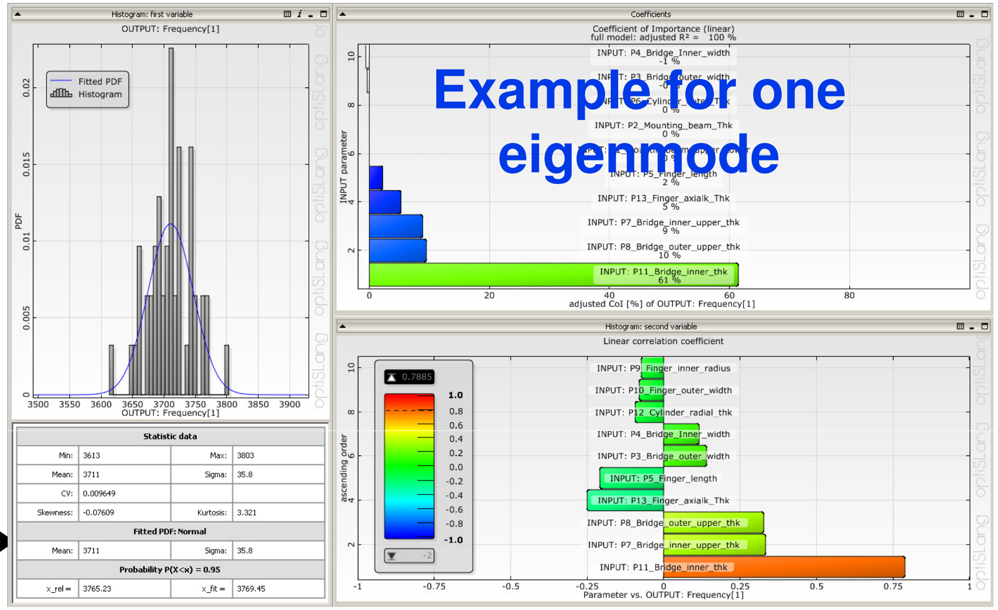
→ **For prototyping STL can be used directly**

Target

- **Design space for the optimization / robustness problem is the drawing tolerance of the component**

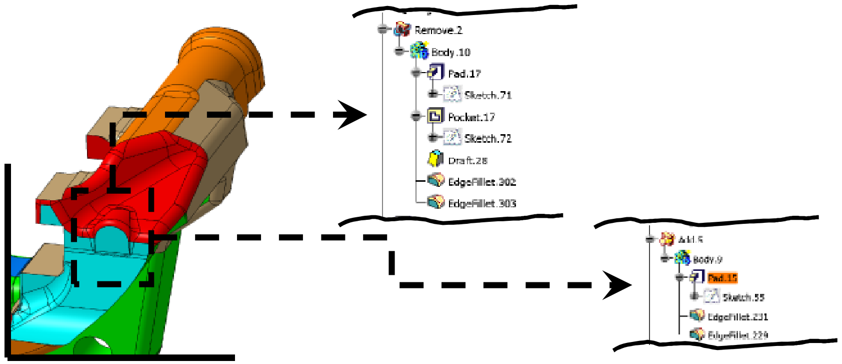
Sensitivity Study

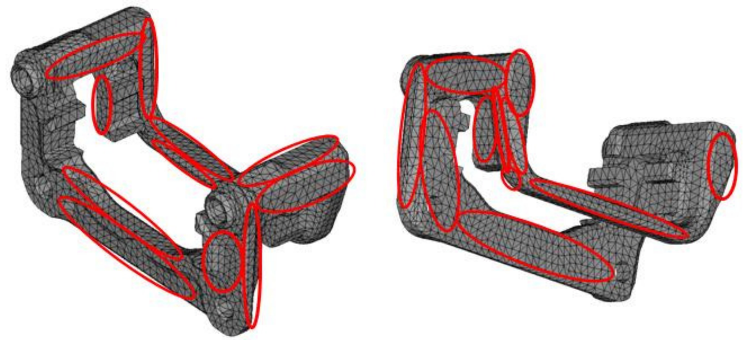




- Parameter field is scanned by random variation of parameters

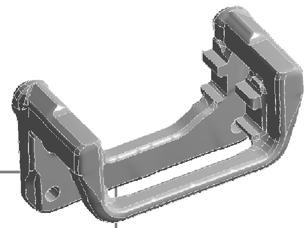
Influence of Parameter Setup

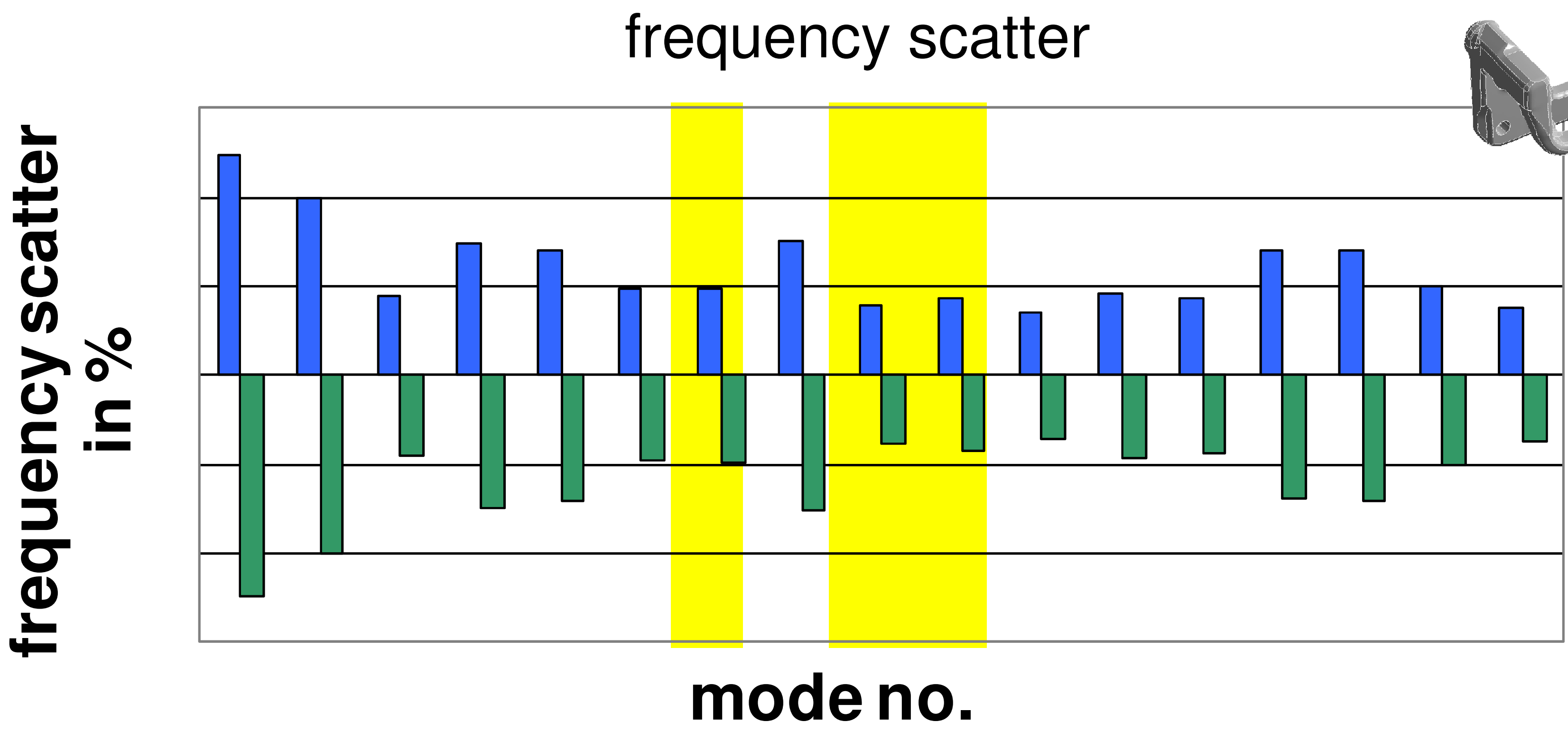




- **Parameter Setup 1 (CAD based)**
  - 175 independent parameters (300 at all)
  - **500 runs** (**only 251 runs lead into successful geometries!**)
- **Parameter Setup 2 (FEA based)**
  - 25 parameters
  - **50 runs**

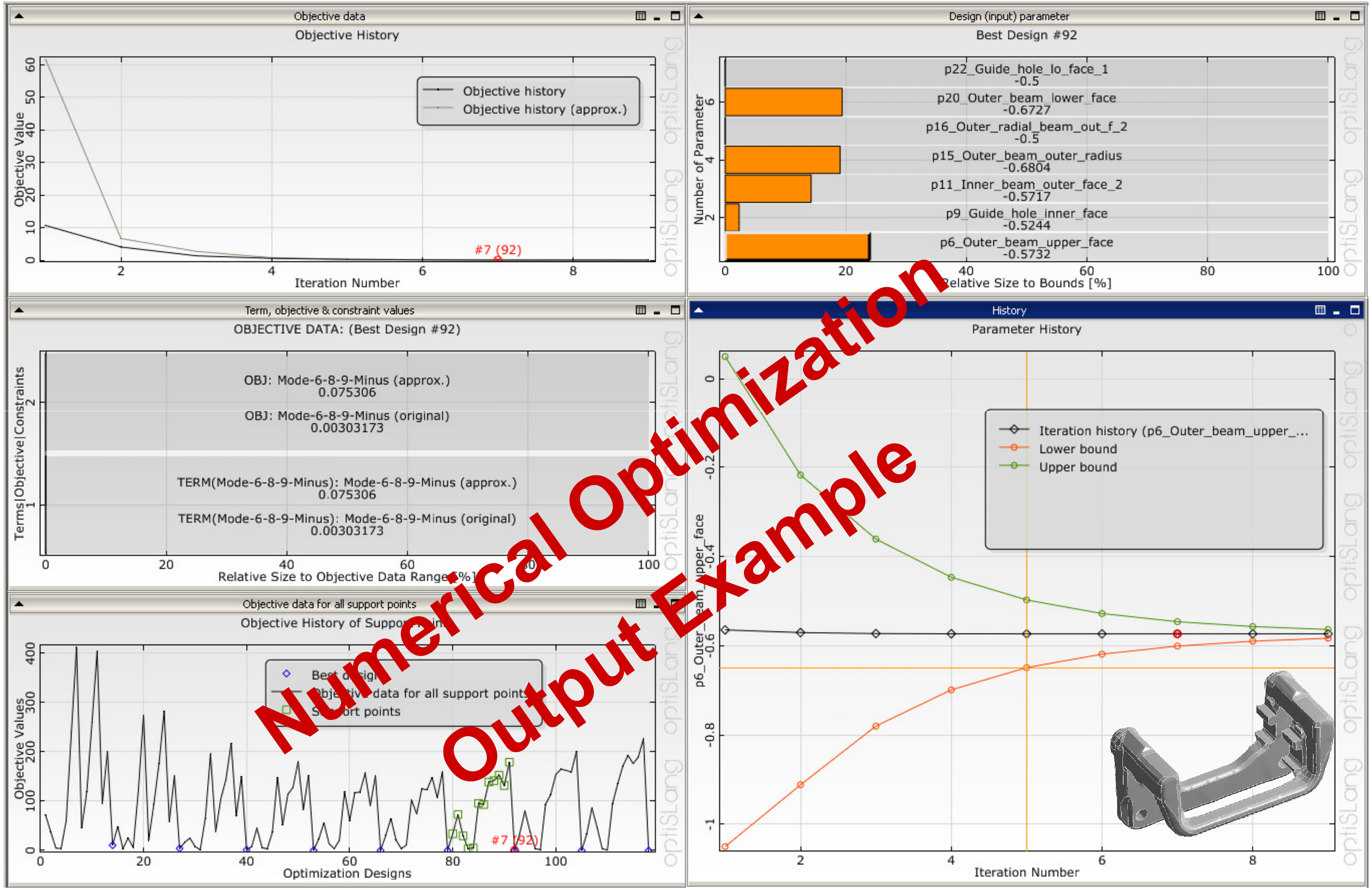
Carrier Frequency Variation





yellow area = relevant component eigenfrequencies for critical noise frequency

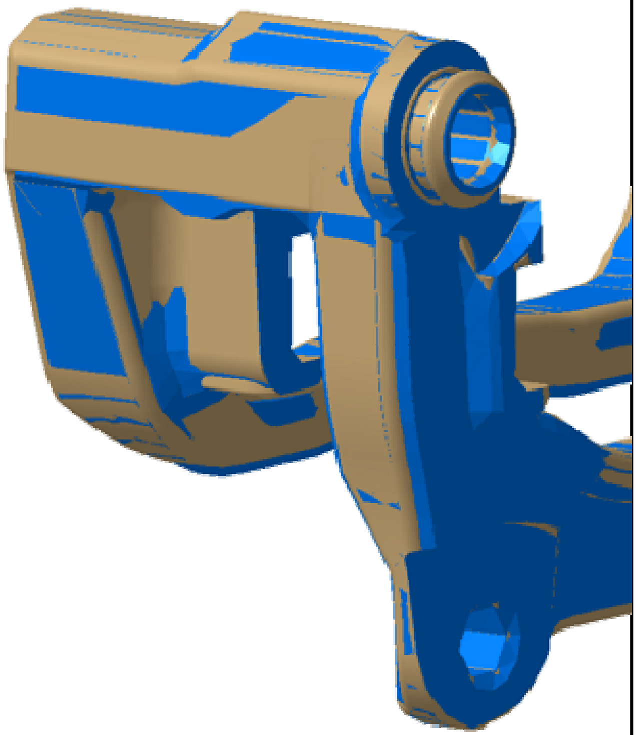
Numerical Optimization



Redesign in CAD

Case Study:

- Brown: original nominal CAD
- Blue: CAE boundary sample proposal, redesign in CAD



Parameter Setup 1 (CAD based)

- Direct usage of CAD parameter

Parameter Setup 2 (FEA based)

- Finite element solution needs redesign in CAD necessary
- STL data can be used to support

Summary and Conclusion

- **CAE sensitivity / robustness studies and parameter optimization are useful to define dynamic boundary samples of brake components**

- **Based on the simulation results**
  - Prototypes can be produced
  - Frequency ranges on drawings can be defined

- **CAE Approach mitigates NVH risk in production and increases NVH quality and robustness**