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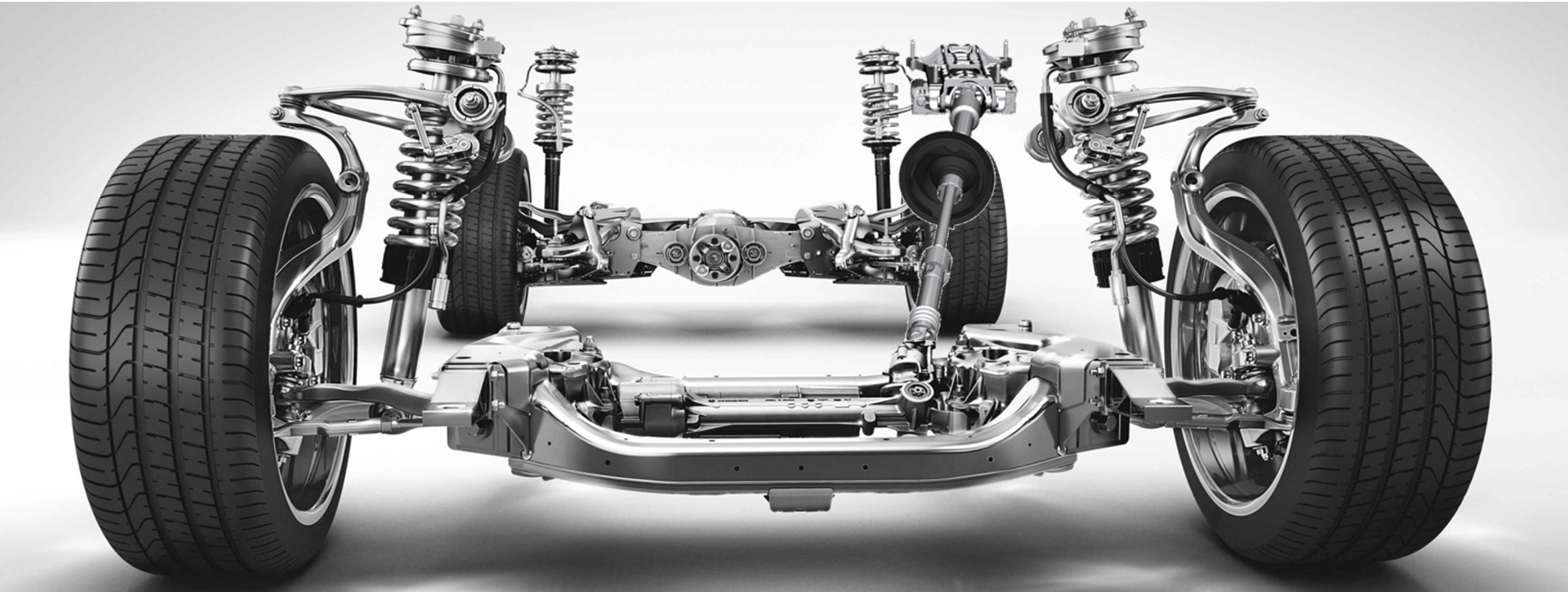


Use of Random Fields to Characterize Brake Pad Surface Uncertainties

Dr. Ronaldo F. Nunes, Oliver Stump - Daimler AG
Dr. Sebastian Wolff - Dynardo Wien

Entwicklung Fahrwerk

Mercedes-Benz

05. November 2015

Agenda

NVH Customer Requirements: Silent Brakes or Robust System ?

Lining Material Surface: Brake Noise Influence

New Workflow Proposal with SoS

Application to a Real Brake System

Summary/Future Development

NVH Customer Requirements:
Silent Brakes or Robust System ?

Entwicklung Fahrwerk

NVH Customer Requirements

Answer:
Our focus is to achieve a NVH robust system for the whole life cycle.

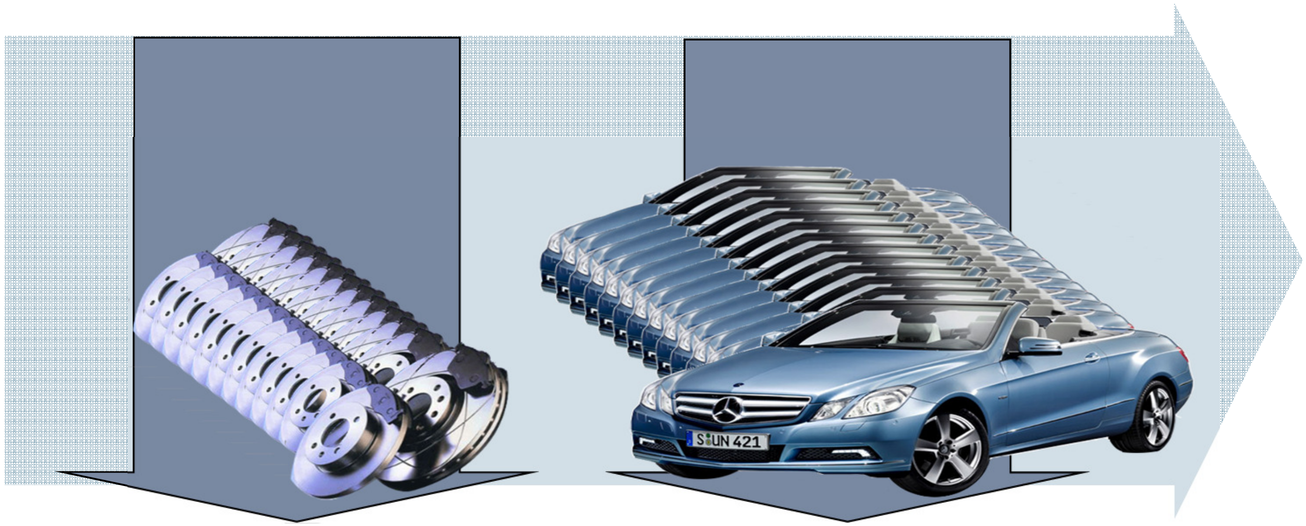
…you get ideal curves with constant slopes at low percentage values

Main Task: Silence Brake System to the Whole Life Process

Problem

Influence of the production dispersion

Influence of drivers and time



Production dispersion:

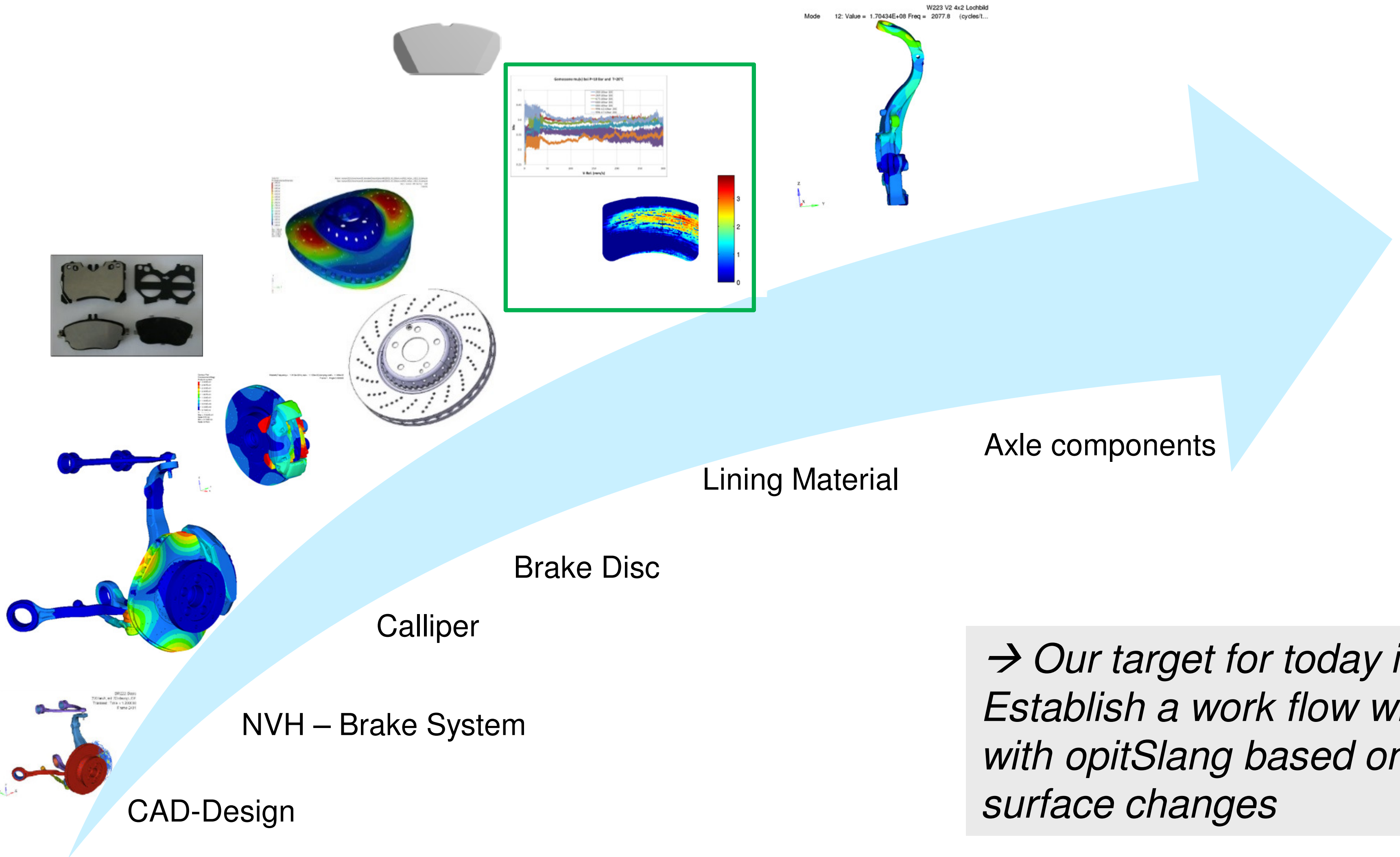
Geometry tolerances (Uncertain Parameters, friction coefficient, weight, etc.

Drivers and time:

Pressure, temperature, friction behaviour, fading, etc.

→ Focus reliable prognostic of brake squeals relative to the production, time and drive conditions to the whole life process

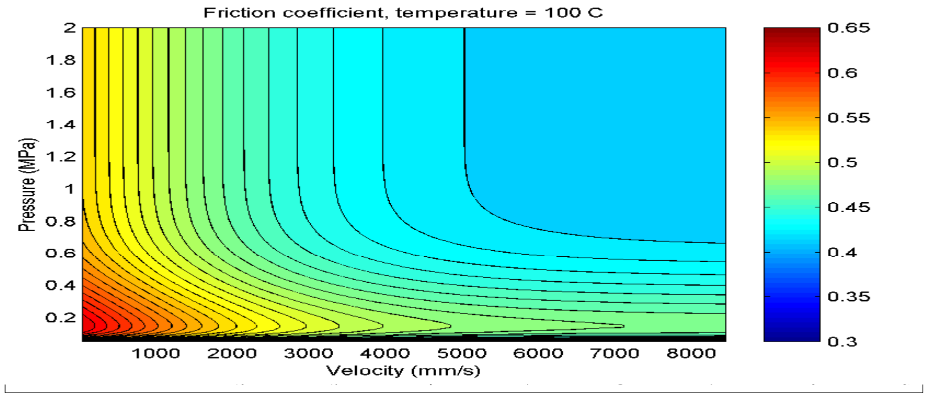
NVH – Brake Components Influence

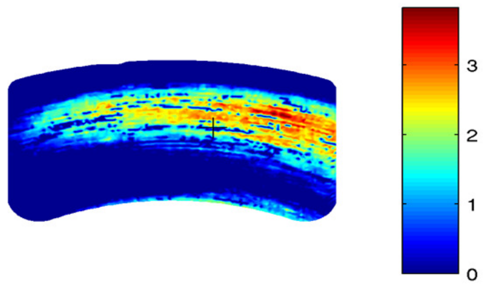


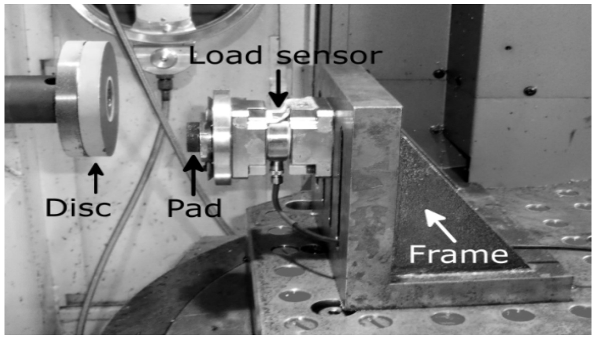
Target: Robust Brake System to the whole life process

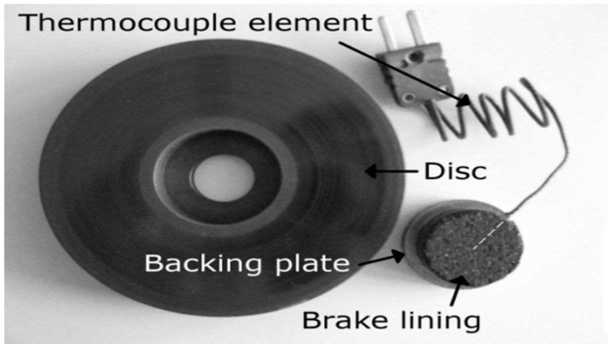
→ Our target for today is …
Establish a work flow with SoS combined with opitSlang based on lining material surface changes

Alternative 1: Integration of Friction Curve and Surface Change in the Simulation Model







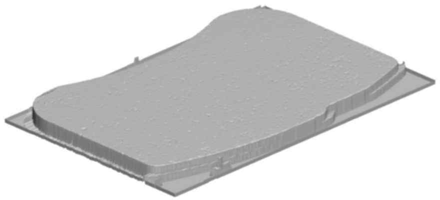


Source: 2012 Heussaff: Influence of the variability of automotive brake lining surfaces on squeal instabilities

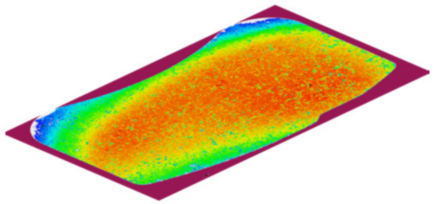
→ Possibility to integrate the friction curve in the simulation model

Alternative 2: Work flow SoS Combined with OptiSlang

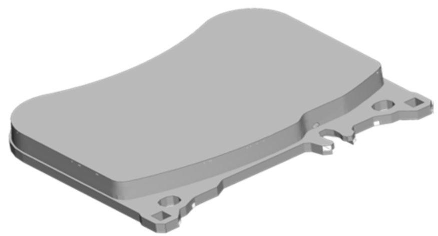
New Work Flow !



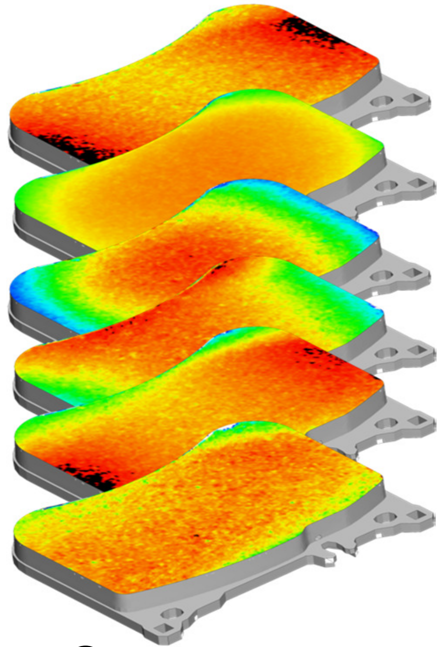
Laser scans of brake pad <u>whole</u> surfaces



Import of scan data into SoS



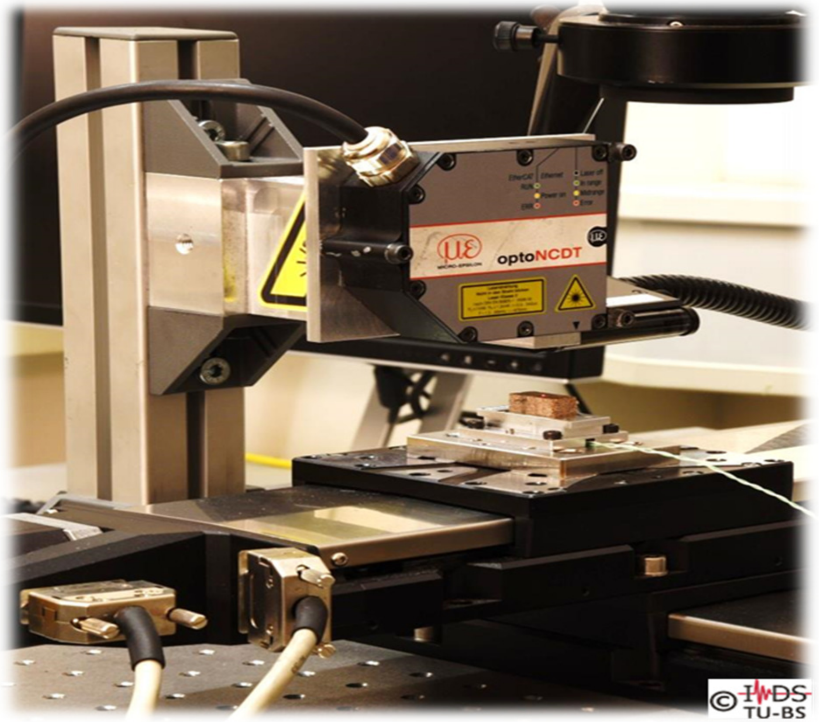
Map data onto FEM model surface and create random field model in SoS



Generate new random geometries with **optiSLang + SoS**

IDS Topography Measurement Station

Topography Measurement



Measurement Station

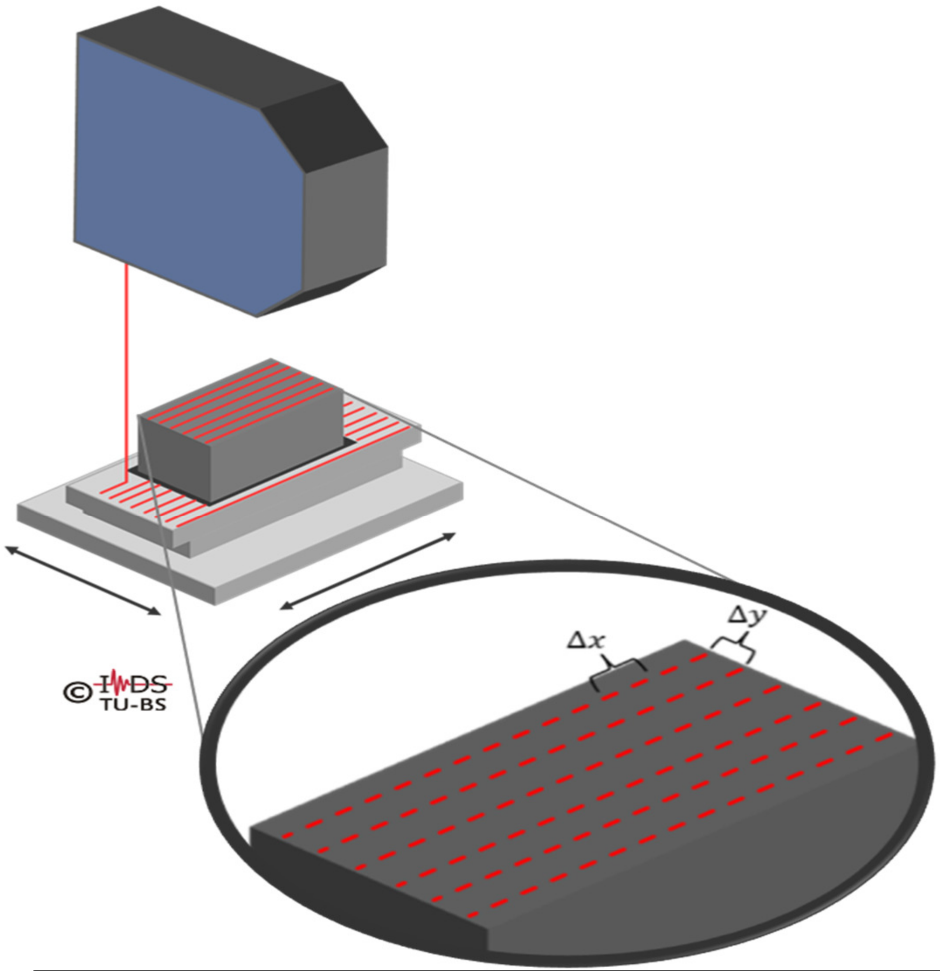
- Laser Triangulation Sensor with 0.5 µm repeatability and max. 6 µm linearity deviation
- Contactless measurement of distance between specimen and sensor
- No destruction of the surface
- Moving the specimen on two linear stages with a positioning accuracy of 2 µm
- Measuring range of the height up to 10 mm

Detailed Information, see [1]

[1] Ostermeyer, G.-P.; Perzborn, N. and Ren, H., ***Contactless Wear Measurement of Brake Pads***. In: EuroBrake 2013 Conference Proceedings

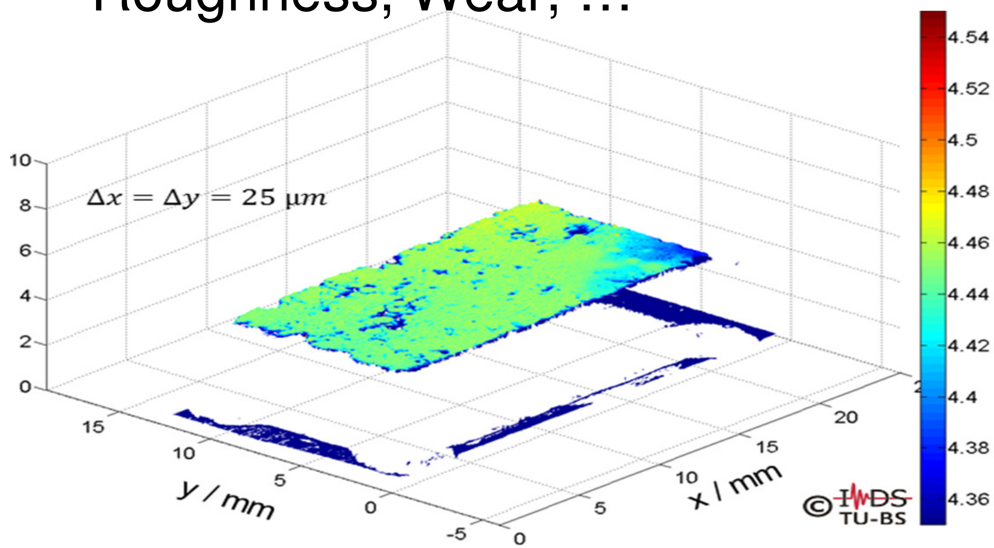
IDS Topography Measurement Station

Topography Measurement



Measurement Procedure

- Measuring the topography by combining line profiles
- Lateral resolution up to 10 µm
- Usable to determine Contact Surface, Geometric Properties, Roughness, Wear, …



IDS Topography Real Measurement

Topography Measurement

Measurement Procedure

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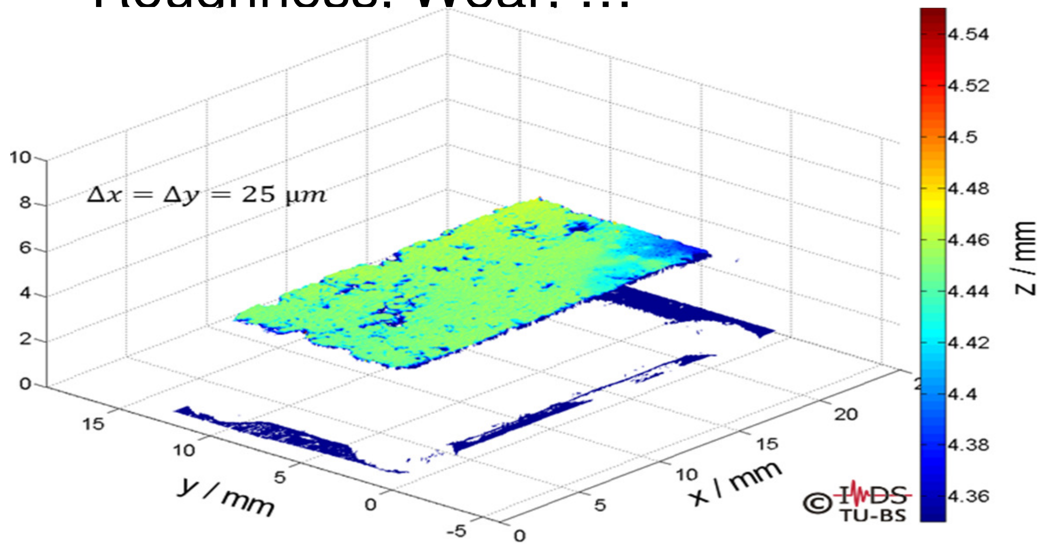
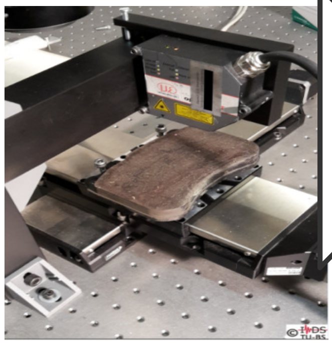
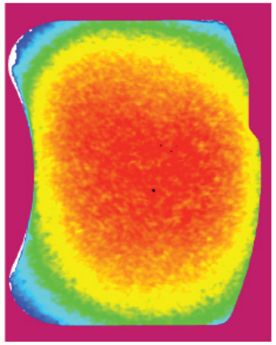


Workflow

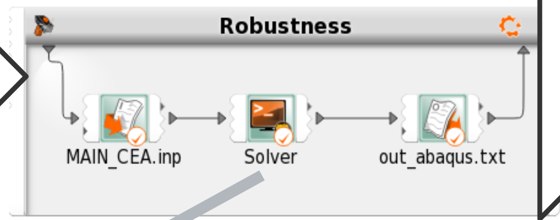
Measurements (TU Braunschweig)



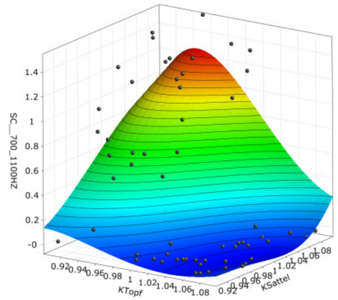
Mapping to FE-Mesh (SoS)



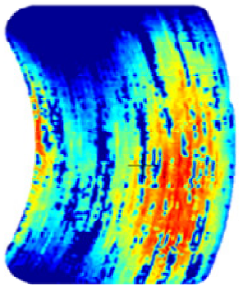
Robustness Analysis (optiSlang + SoS)



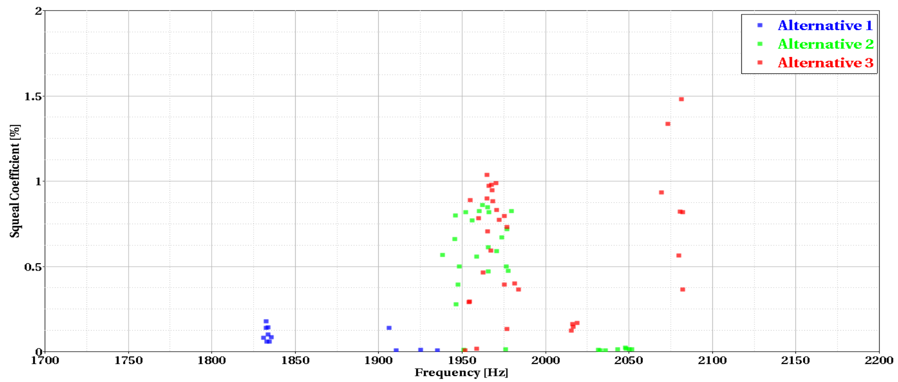
Evaluation with optiSlang



Nonlinear Contact (Abaqus)

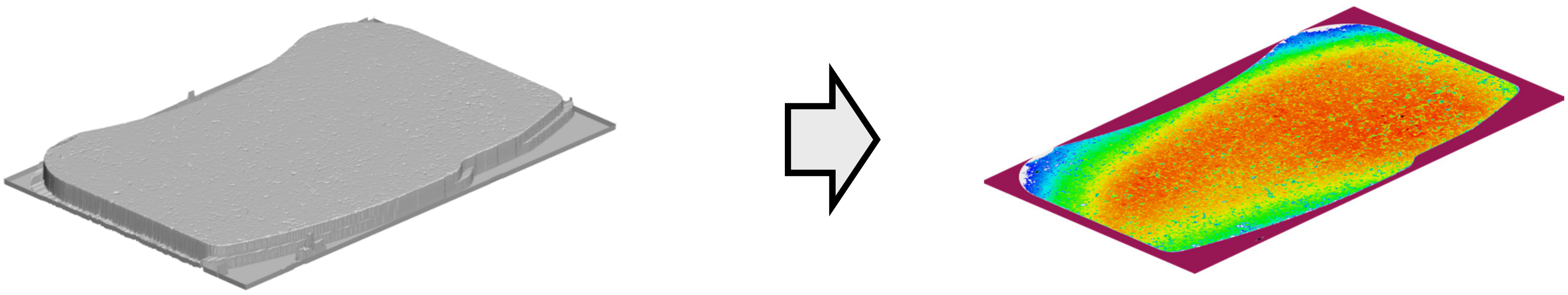


Evaluation with a post processing Script (HyperView)



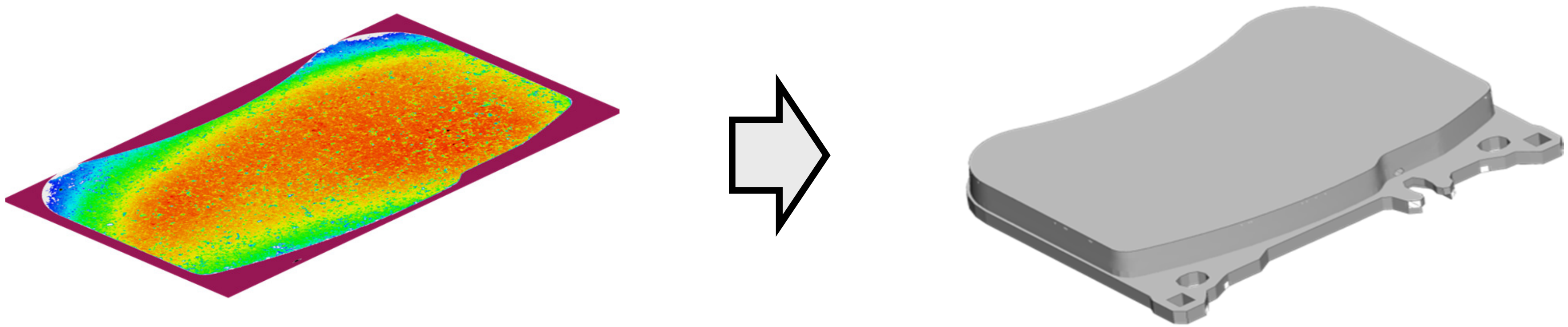
Step 1
Import laser scan data into SoS

- Laser scan data: 1.2 million measurement points on a 2D grid
- 40 real measurements
- Import of grids with variations in Z position in terms of a scalar field “Deviation”
- Visualization of the deviation as color plot in SoS
- Further: Rotation, Translation and scaling (units!) in SoS



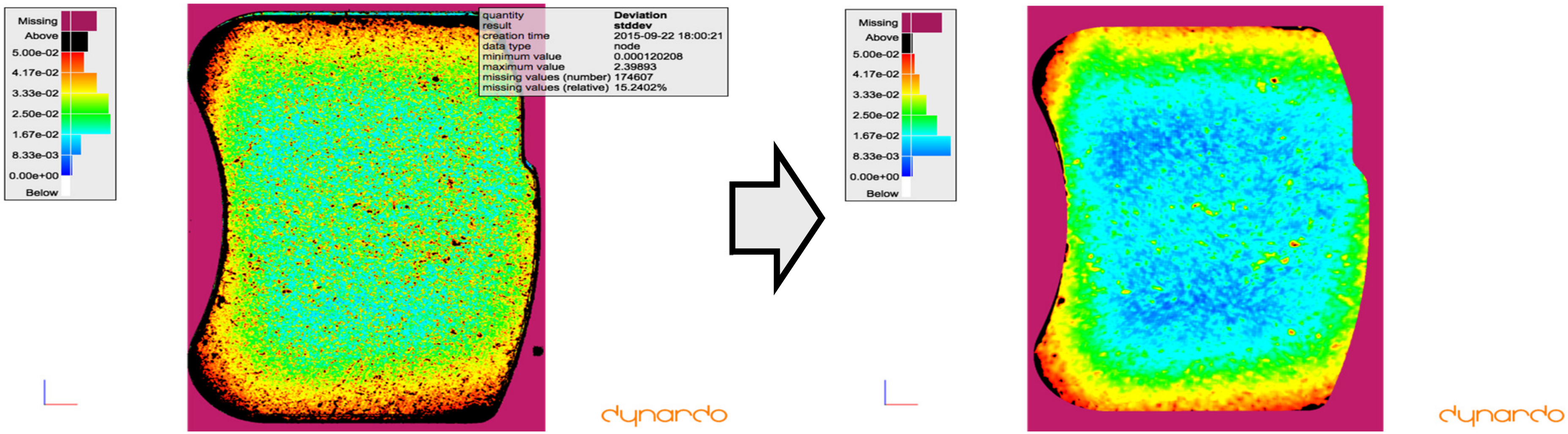
Step 2
Mapping of measured data onto FEM mesh

- FEM mesh of break pad: 118558 nodes, 405971 elements,
- Abaqus INP file format, target surface defined by node set
- Projection along predefined direction (y axis)



Step 3
Mapping of measured data onto FEM mesh

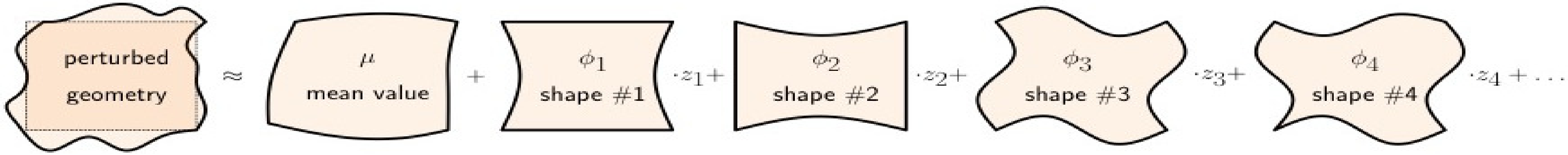
- Loss of information due to data mapping!
- Reason: Rough spatial resolution of FEM nodes vs. small distances of laser scan points
- Nearly no differences in statistical mean
- But: Averaging effects in standard deviation (i.e. spatially very local effects)



Random field model

Approximate a random design with

- mean value +;linear combination of deterministic “scatter shapes” multiplied with random coefficients



Accurately resembles

- Statistical moments (mean, standard deviation…)
- Spatial correlations (anisotropic, inhomogenious…)

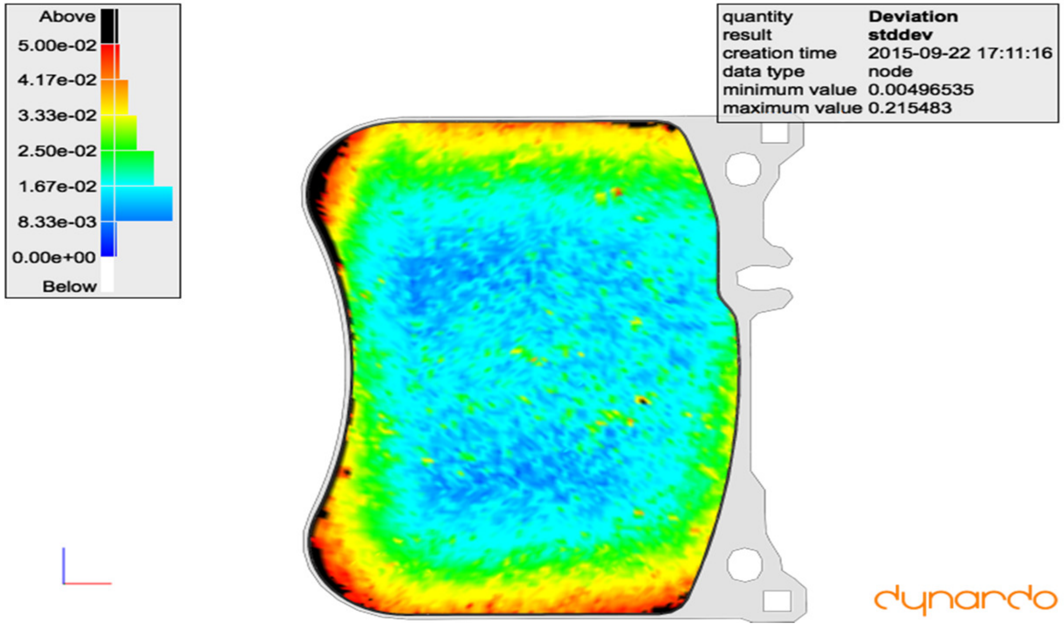
Accuracy:

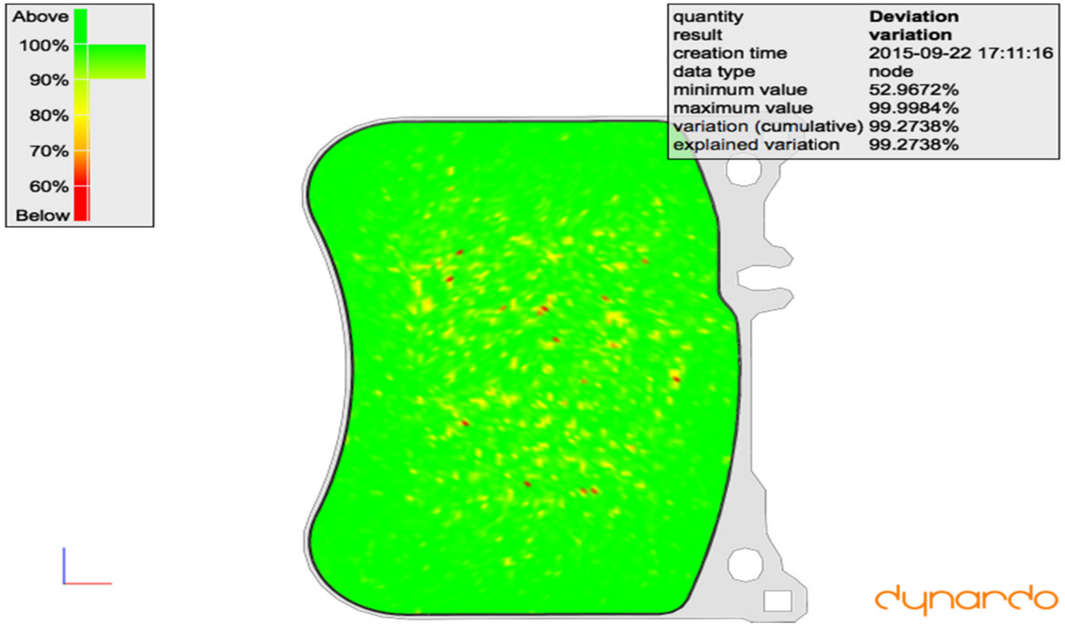
- ~30 random numbers to approximate statistics of measurements with 99% accuracy
- Only 10 random numbers for 90% accuracy

Random field model: Accuracy

Left: Standard deviation in FEM model

Right: Accuracy in %

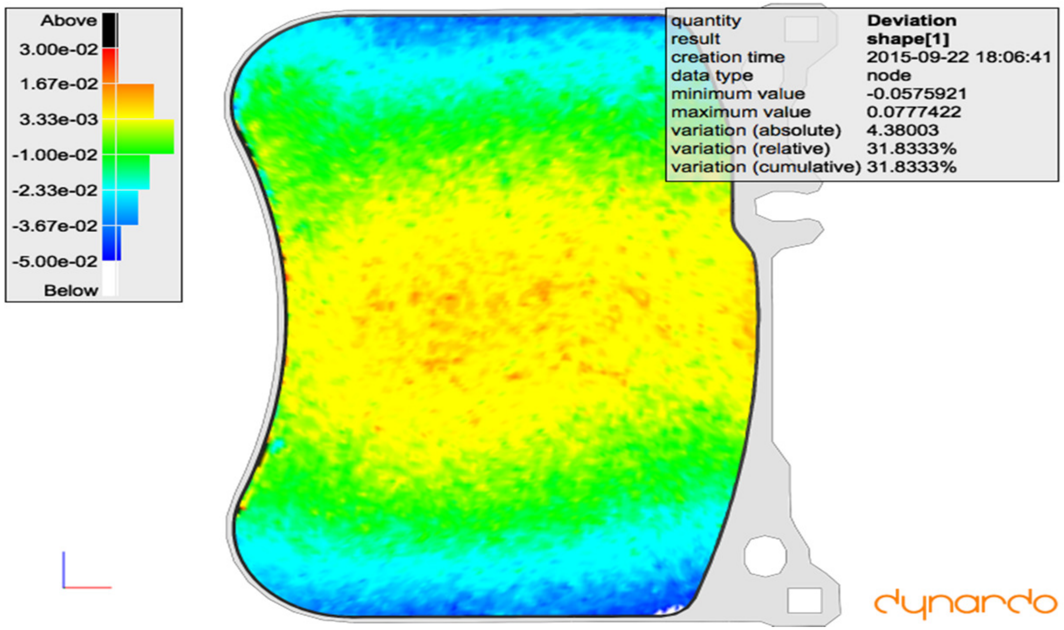


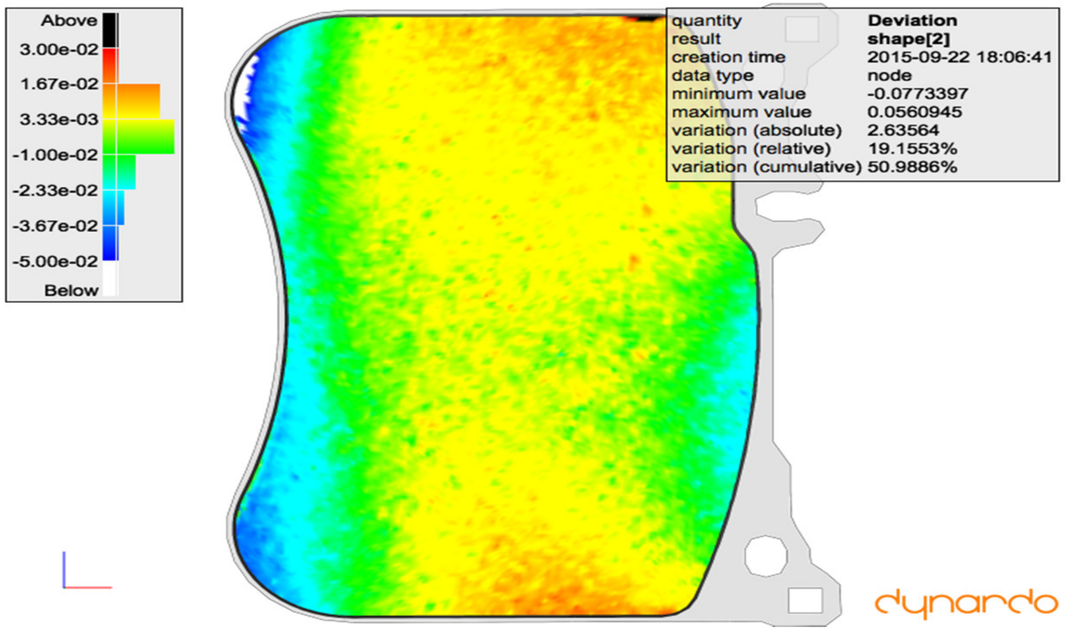


Random field model: Scatter Shapes

Left: Shape #1 (31.8% Variation)

Right: Shape #2 (19.1% Variation)

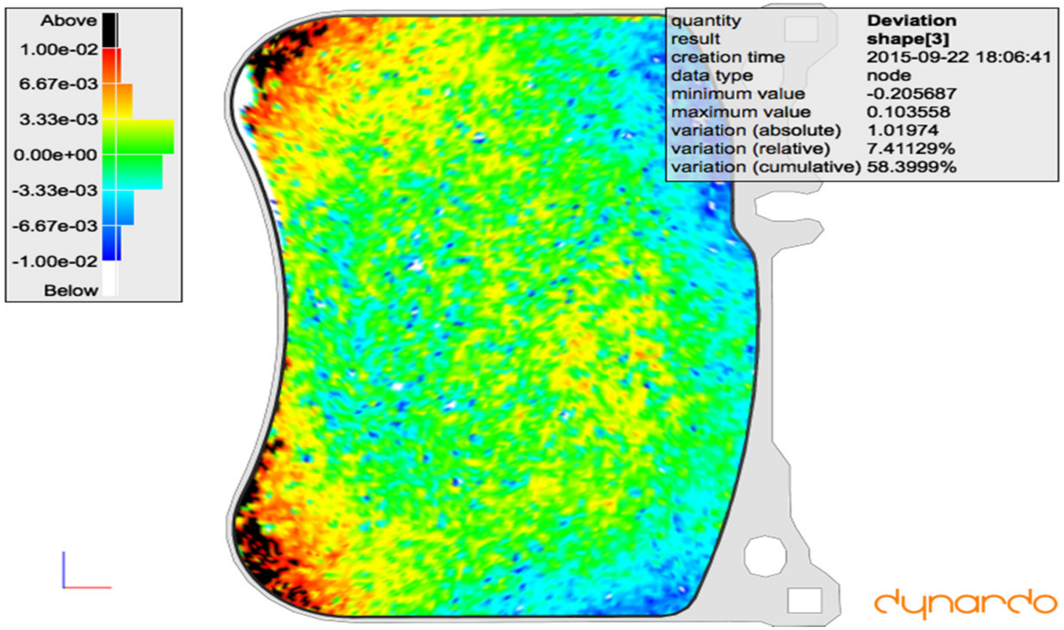


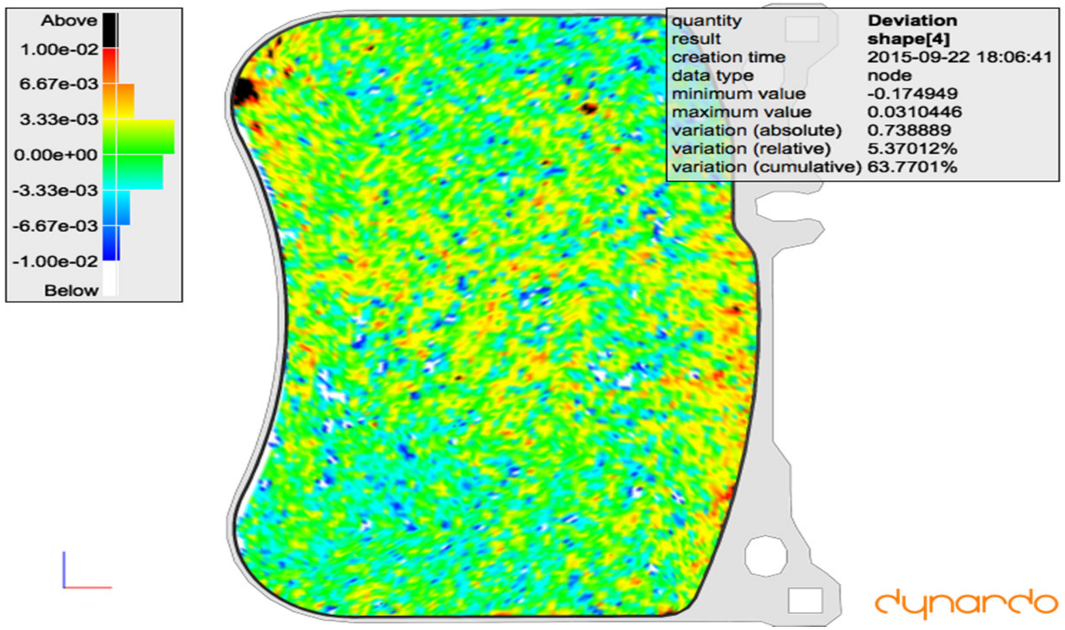


Random field model: Scatter Shapes

Left: Shape #3 (7.4% Variation)

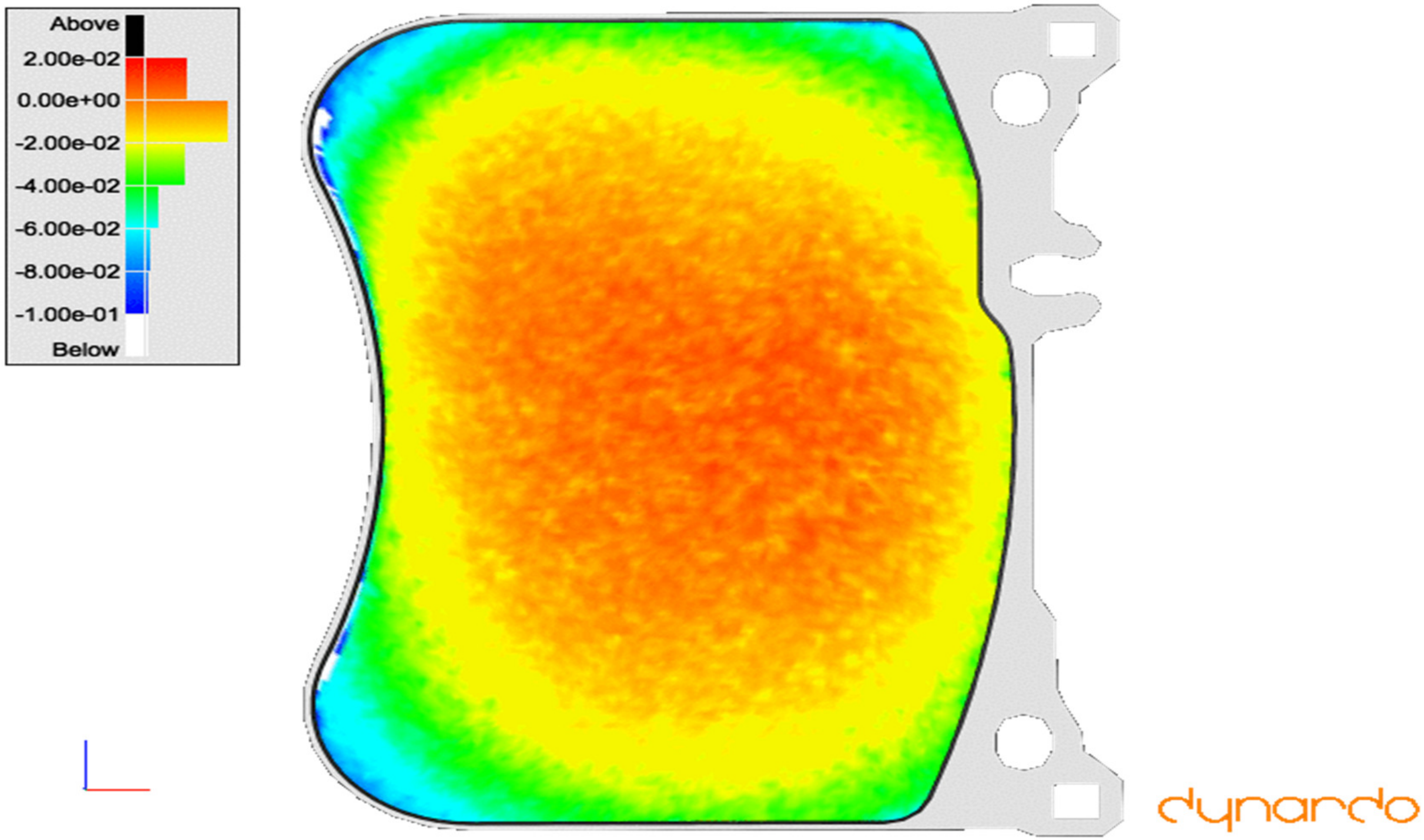
Right: Shape #4 (5.4% Variation) – already with many local effects





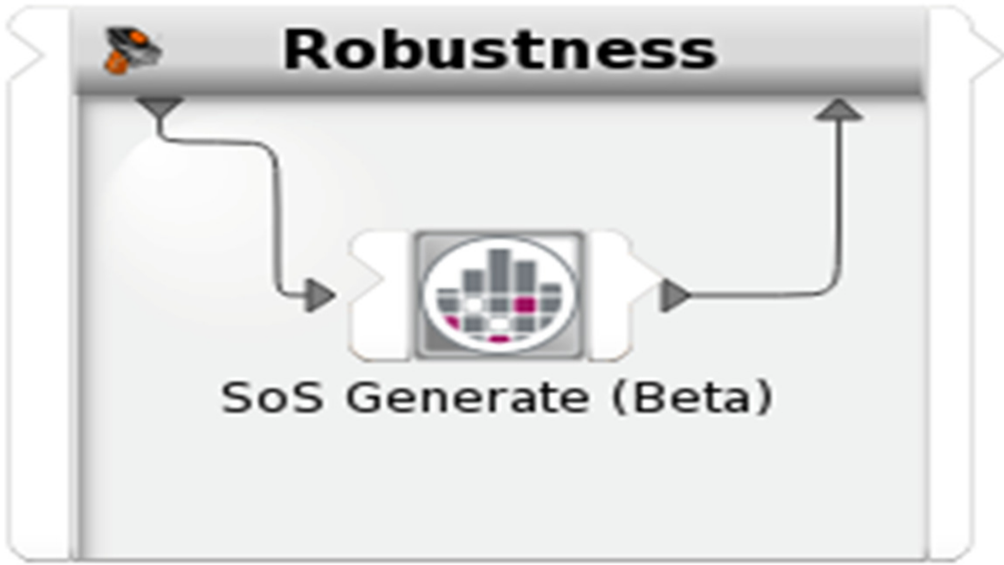
Random field model

Video shows some possible realizations of the random field



Simulation of new random designs

- Use optiSLang to generate 100 new random designs
- SoS will be started in Batch mode by optiSLang
- Depending on desired accuracy: Use 5, 10 or 30 random parameters to generate geometric imperfections

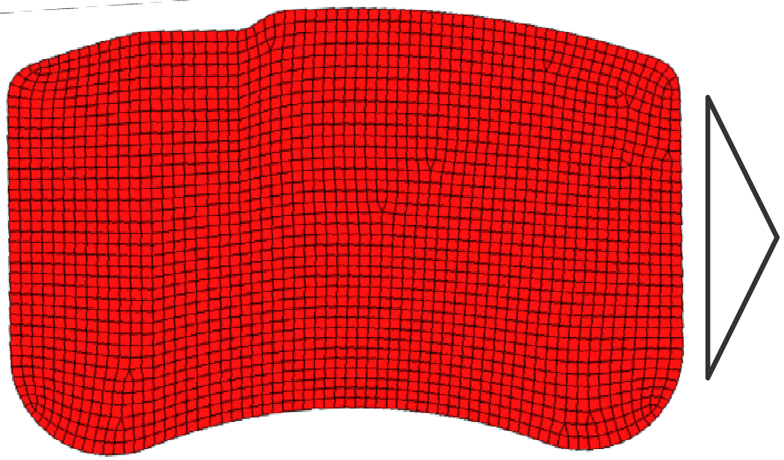


Surface changes influence nonlinear contact finding

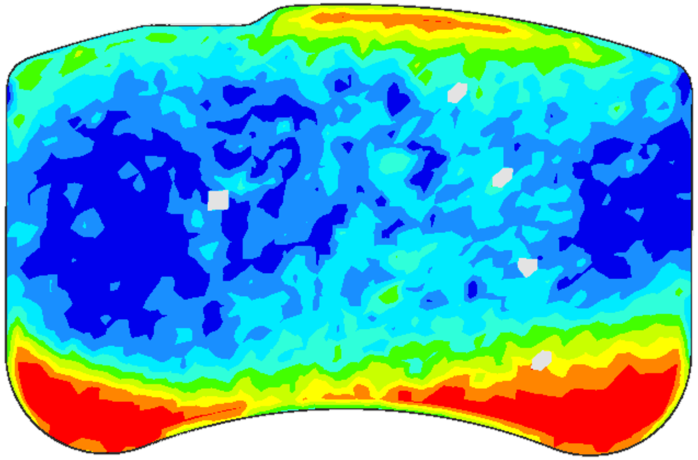
- ❑ Well-known behavior:

→ Instability is strongly influenced by the pad / disc contact

- ❑ Presented workflow enables **simulation of the measured and mapped brake pad** and **the generation of new, correlated surfaces**
- ❑ Mapping is dependent on the refinement of the mesh



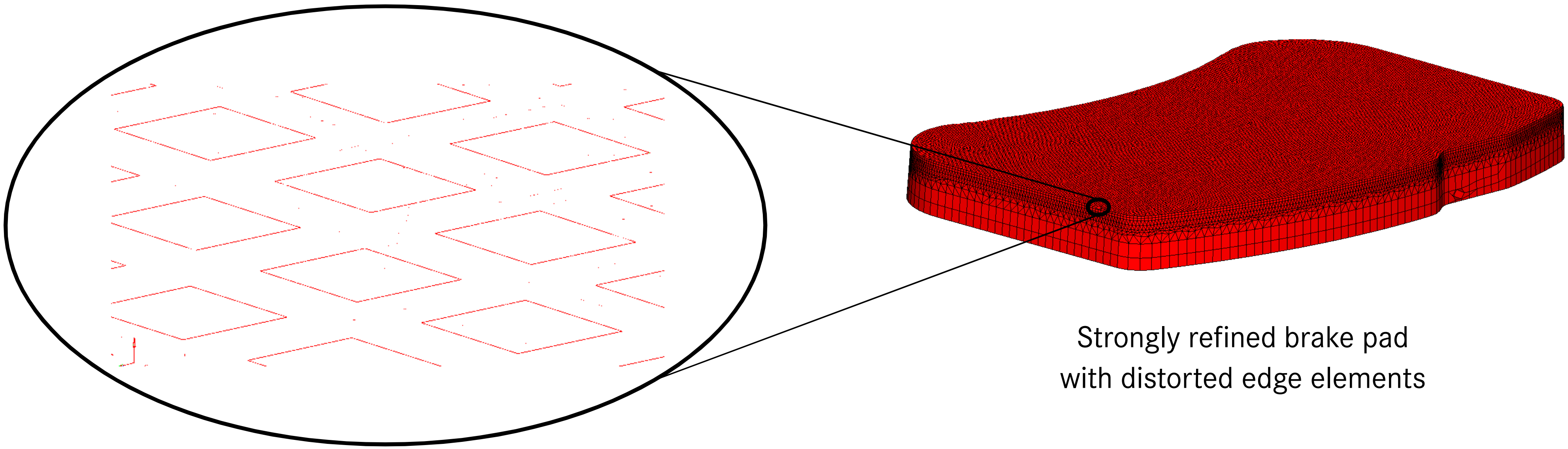
Standard meshed brake pad



Contact opening (pad/disc) example of the simulated brake pad

Challenges with Random Generated Surfaces

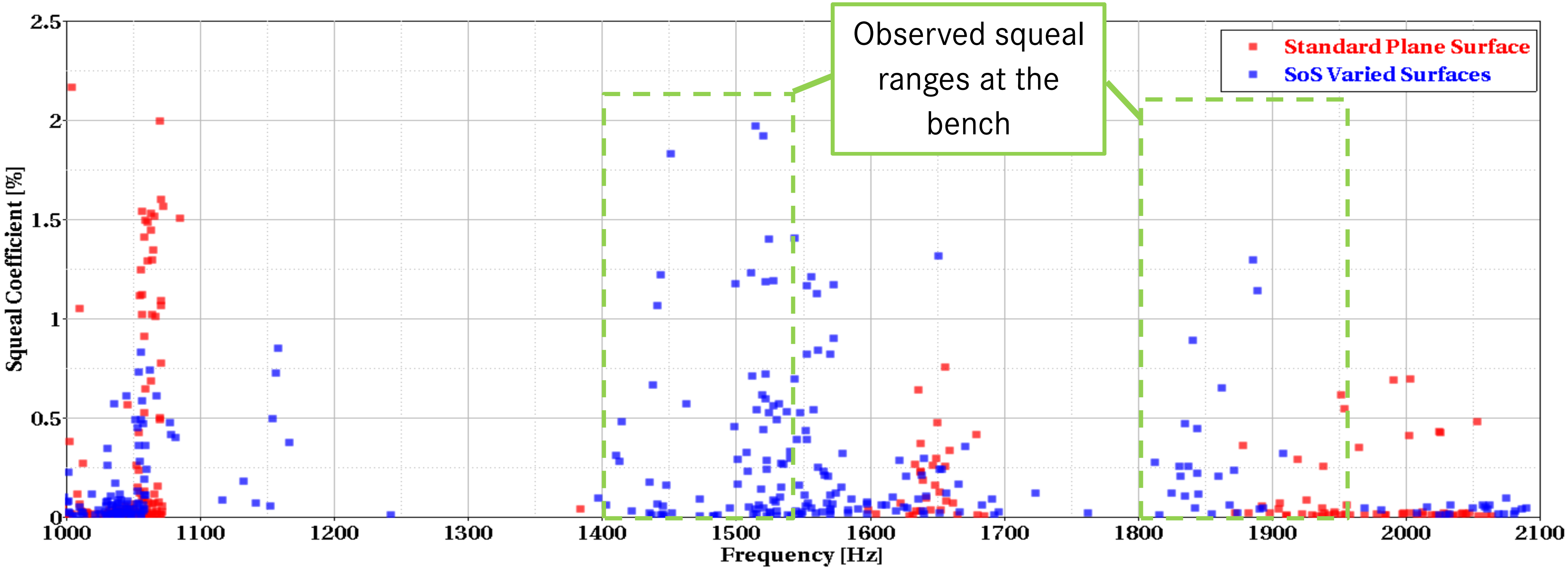
- Mesh quality must be observed
- Especially with edge extrapolation, mesh elements can easily be distorted
- Workflow implementation for the refined meshes is still work-in-progress



Strongly refined brake pad
with distorted edge elements

Example Robustness Analysis Result

- ❑ Standard Robustness analysis consists of 100 random designs
- ❑ New Analysis adds random surfaces to the same random designs



→ Higher instabilities occur with a slight change in frequency
→ The frequency at ~1 kHz decreases (→ frequency not observed at bench tests)
→ Mode shapes and contact conditions have to be evaluated carefully

Summary/Future Development

- Automatic positioning of measurements along the reference grid
- Improvements to random field model being used:
  - Non-Gaussian random fields to capture measured statistics more accurately (Non-Gaussian random field amplitudes and Non-Gaussian field realizations)
  - Enforcement of lower and upper value bounds of field realizations (mostly due do numerical requirements)