FESTO

Optimization of a magnetically prestressed valve actuator

16. Weimarer Optimierungs- und Stochastiktage 2019

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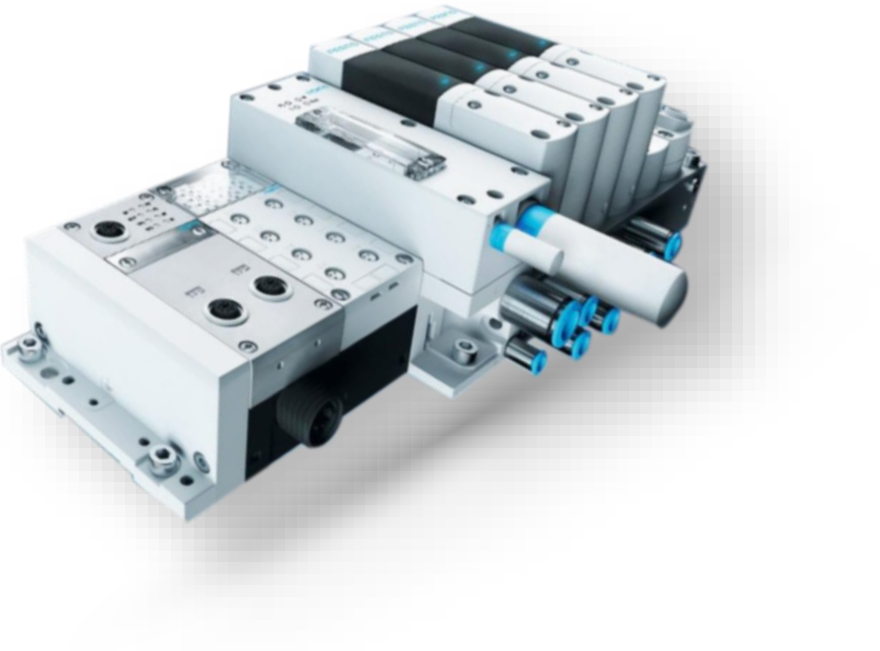
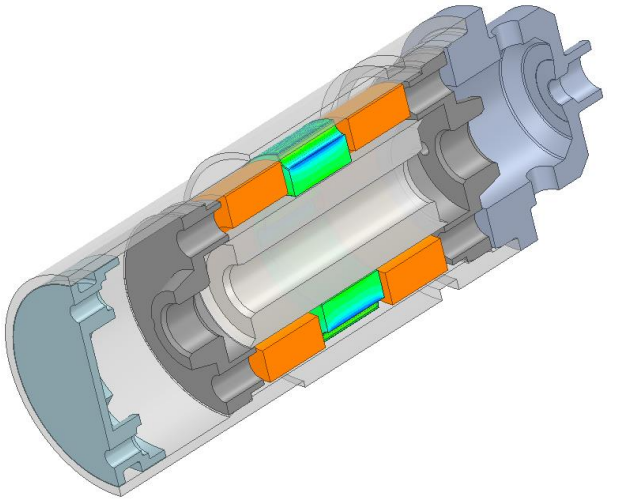


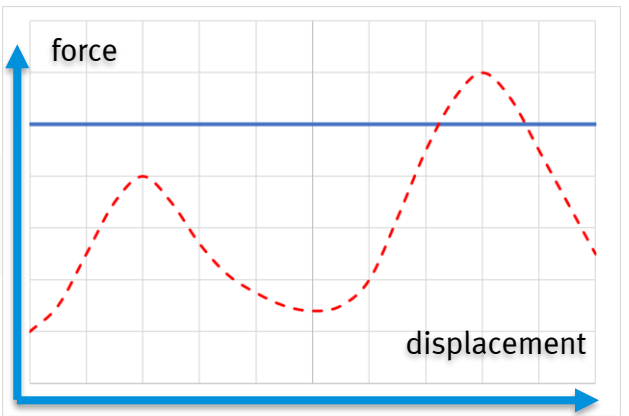
Agenda

- **Motivation and Target**
- Electromagnetic field simulation
- Workflow
- Sensitivity study
- Optimization
- Results and Perspective

What is the point?

- **Target**
  - Development of an actuator for a proportional valve
  - Straight force-displacement curve
- **Implementation by**
  - Polarized magnet system
- **Challenge**
  - High non-linearities in material behaviour
- **Until now**
  - Experience based parameter studies
- **Procedure**
  - **Systematic, parameter based optimization using Ansys optiSLang**

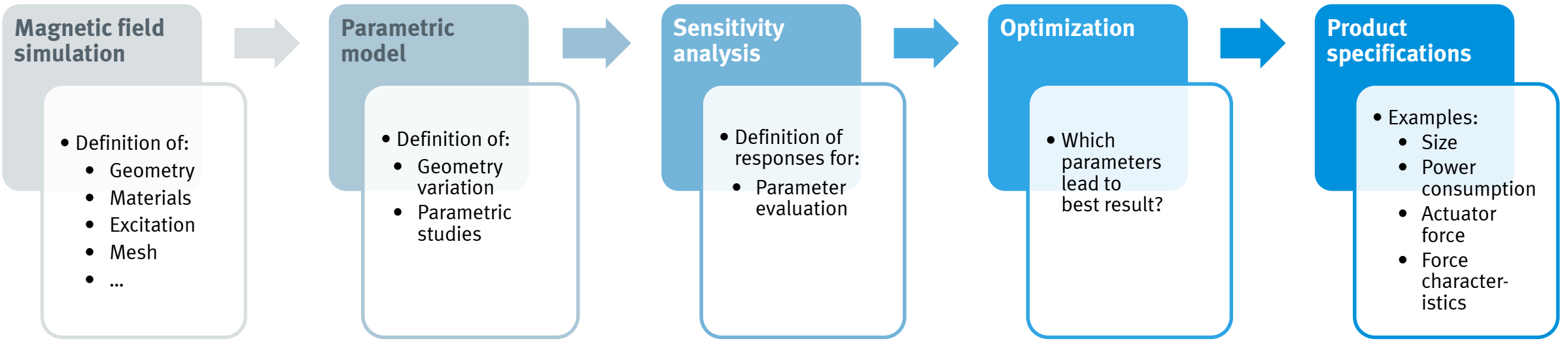




F = F (i)
Current dependent

F ≠ F (s)
Not stroke dependent

Systematic, parameter based optimization



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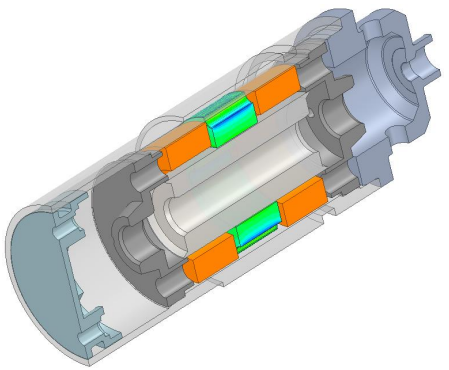
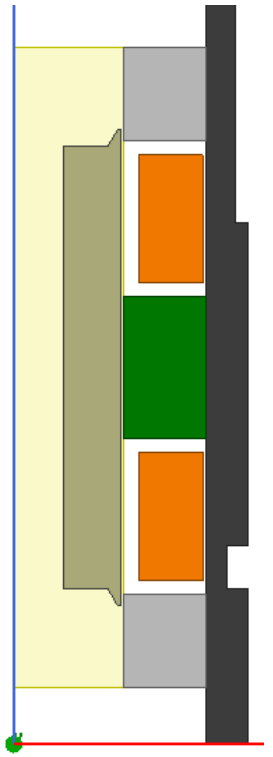
Modelling the magnetic circuit

- Rotationally symmetrical
- 2D-transient model
- **One signal** for **each design**
  - Force vs. Time
  - Force vs. Displacement





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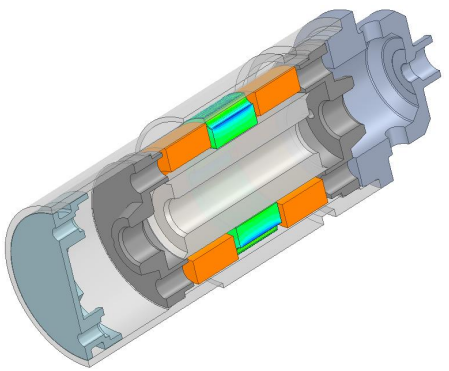
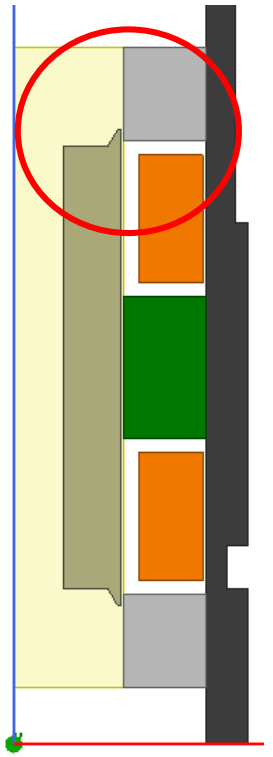
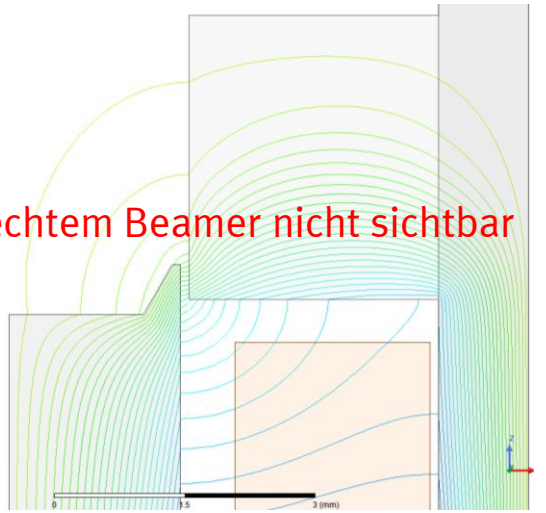




Working principle:

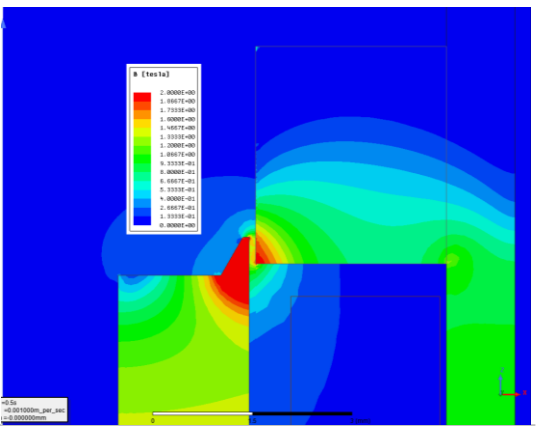
- Reluctance based principle comes with non-linearities
- Saturation and stray fields

Auf schlechtem Beamer nicht sichtbar



BUT:

- Key to get current proportional force displacement curves
- **Optimization focuses on cone geometry**



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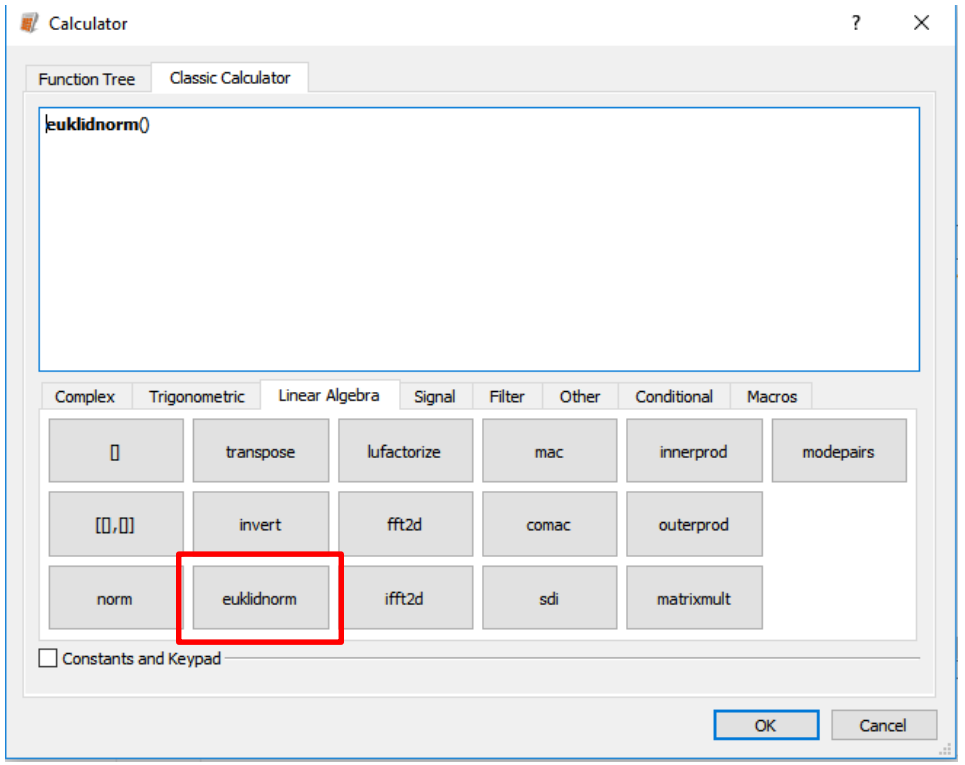
Sensitivity study and optimization need scalar values

1. **Mean value of force-displacement curve:**
   - *mean(SIGNAL)*
   - *„Force_mean“*

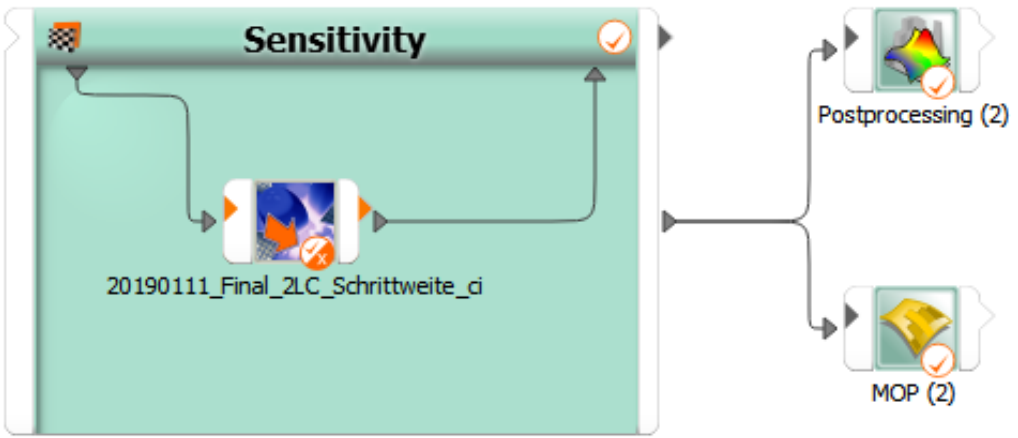
2. **Value describing profile of force-displacement curve:**
   - *euclidnorm (SIGNAL – REFERENCE_SIGNAL)*
   - *mean(SIGNAL)* is used as *REFERENCE_SIGNAL*
   - matching of the signals for values → 0
   - *„Force_profile“*



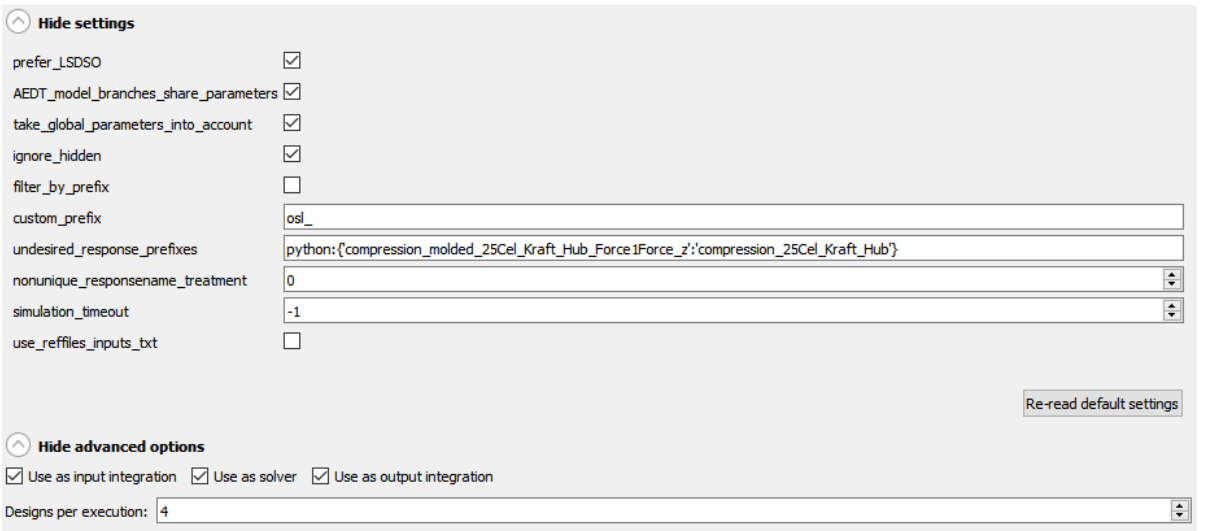
Custom Integration of Ansys Electronics Desktop

LSDSO – Workflow in V7.2.0

- No external configuration files
- No input-files for AEDT
- No extraction of results out of result files
- LSDSO settings located in AEDT-node



Comfortable way to set up workflows for optiSLang driven parameter studies in AEDT



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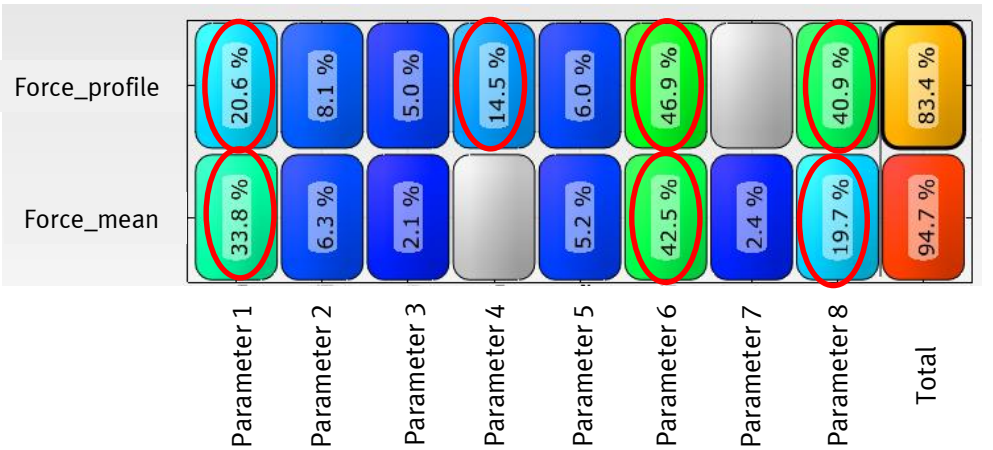
Understanding the system

- **„Coefficient of Prognosis“ matrix**
  - CoP as a measure of the quality for the MOP
  - Dependence between input parameters and the responses
  - Reduction of the input parameters
  - Influence only valid within the given parameter range



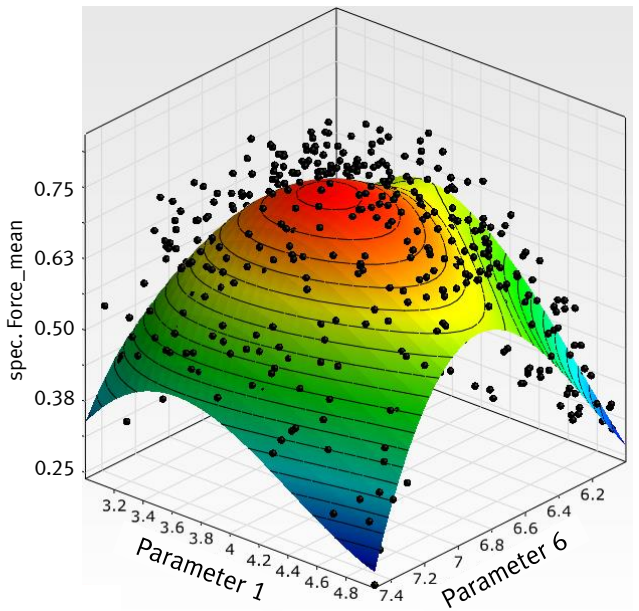
Conclusion:

- „*Force_profile*“ dominated by 4 parameters
- „*Force_mean*“ dominated by 3 parameters

The system behaviour in detail

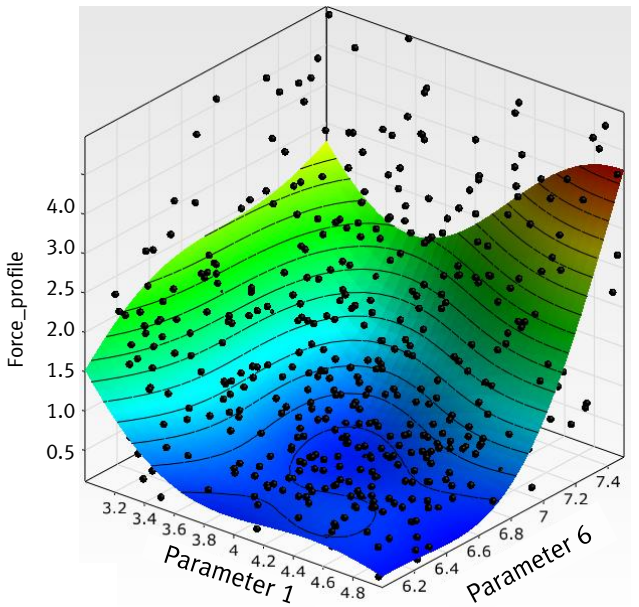
„Force_mean“

- Two main parameters
- **Distinct maximum**



„Force_profile“

- Strong influence of two main parameters
- Caused by saturation effects
- **Check validity of responses!**



- Maximum force dependent on two main geometry parameters
- Force profile dependent on cone geometry
- Separate the two cases

Main parameters are defined

Optimization of cone geometry

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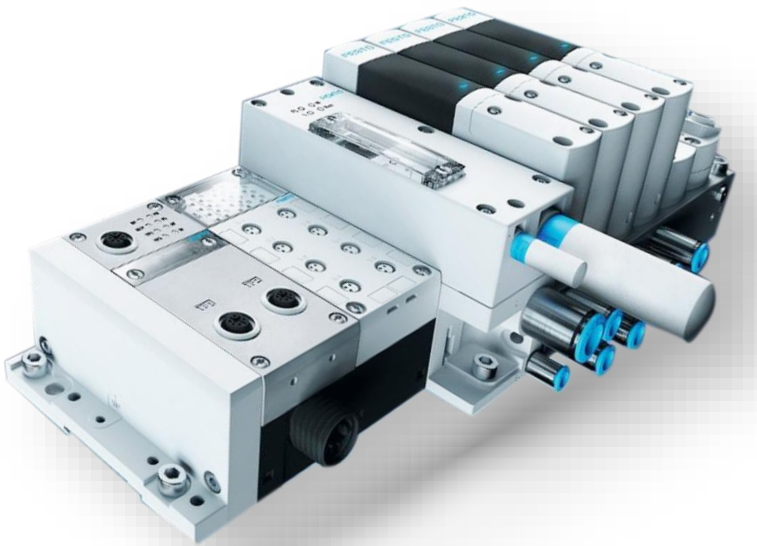
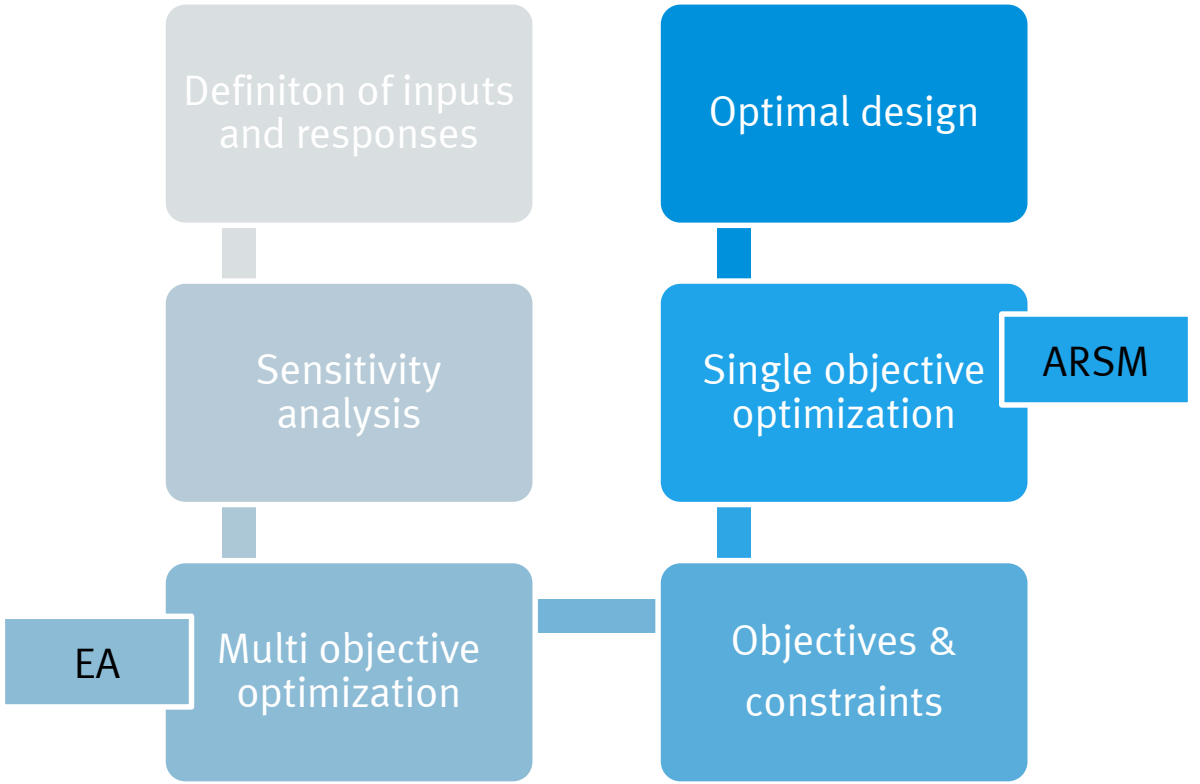
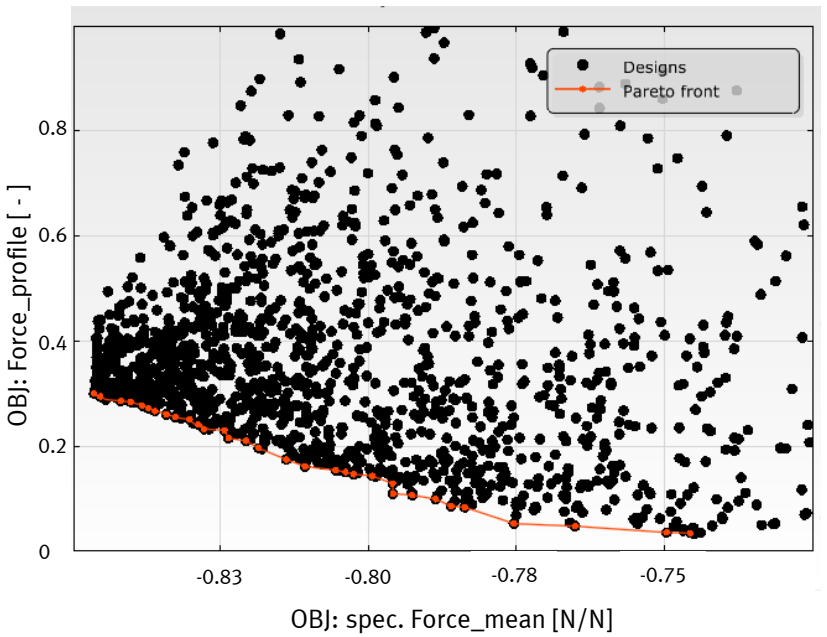


Optimization sequence of cone geometry

- **Two main objectives**
  - **Maximum force** vs. **appropriate force-curve**
- **Multi objective optimization**
  - Objective vs. Objective
  - Target is a compromise between the objectives
  - Pareto-front as decision base for constraints
- **Single objective optimization**
  - Objective vs. Constraint
  - Leads to optimal design depending on chosen objectives

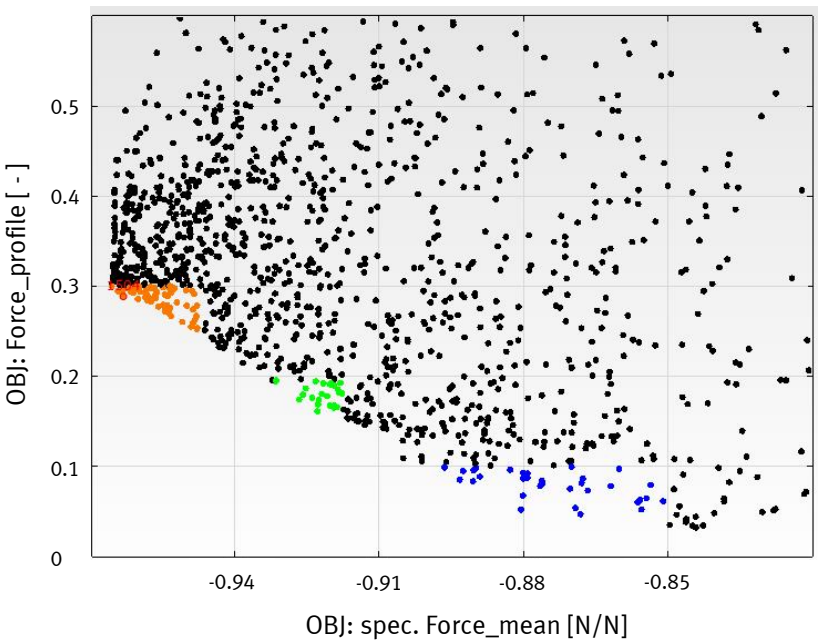


Multi objective optimization



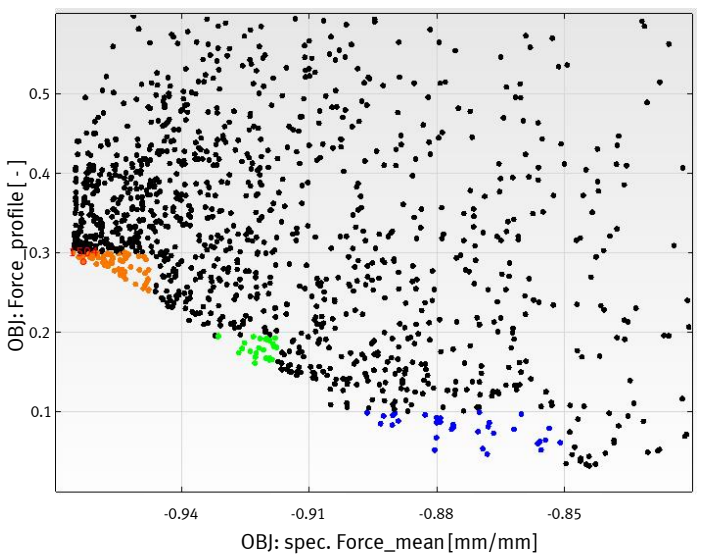
Use colors to visualize different areas

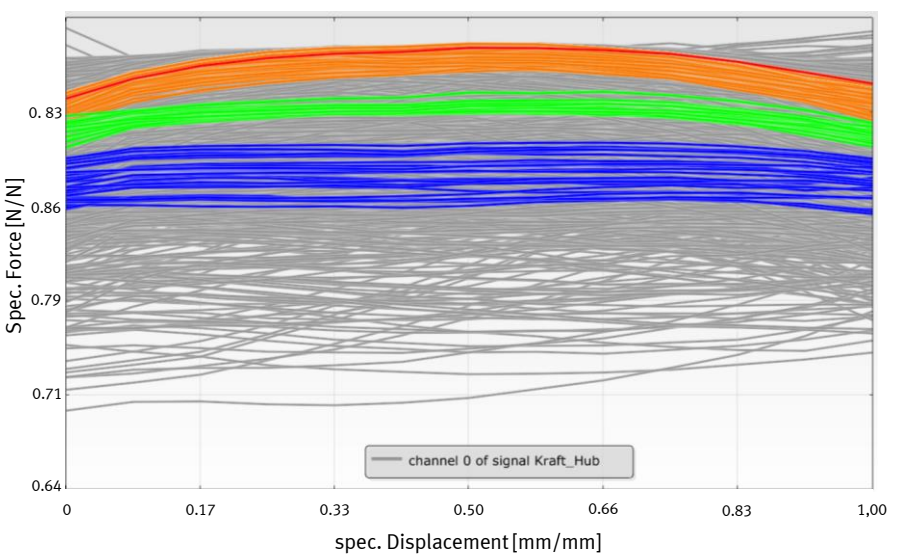
Cluster analysis

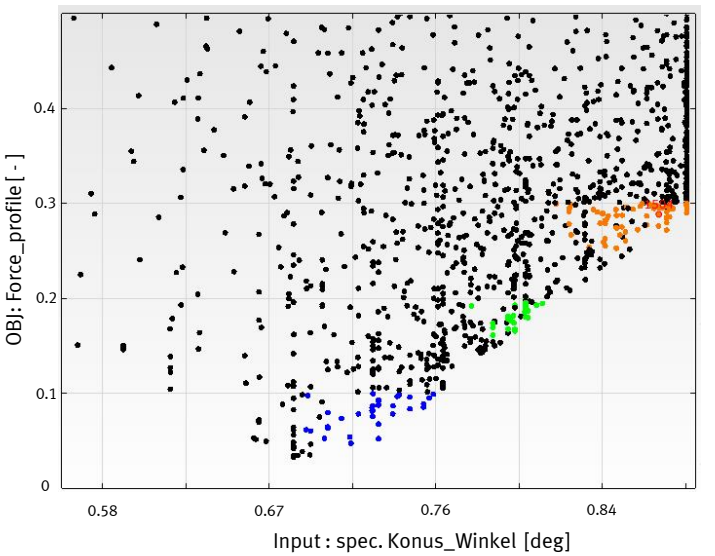


Cluster analysis

- Cluster analysis of the pareto front designs helps to understand the mapping between inputs and defined objectives
- Compromise between objectives highlighted by manual selection
- **Colored clusters are useful for defining start designs for single-objective optimization**

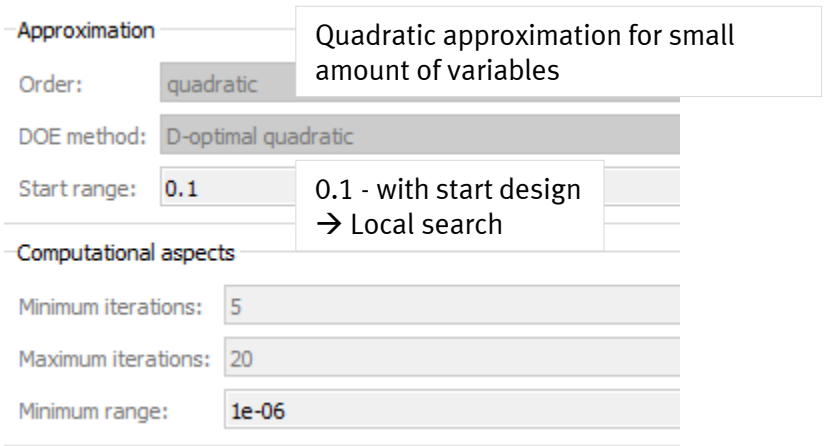






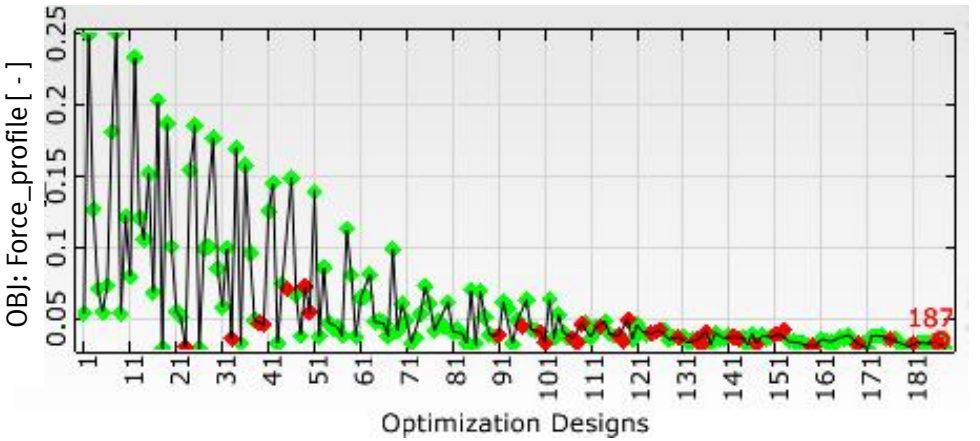
Single objective optimization using ARSM

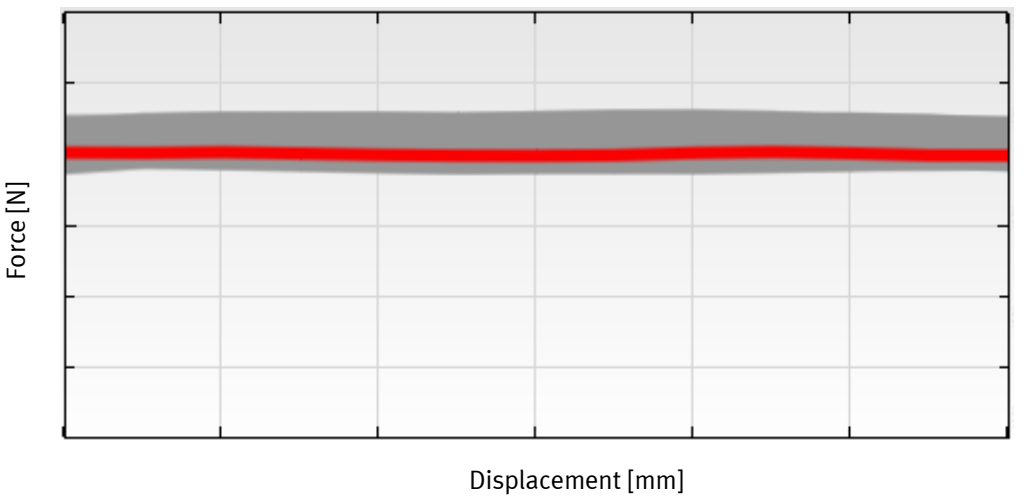
- Colored clusters from multi-objective optimization used as start design
- Local search possible
- Fast convergence after 188 designs
- **Several optimal designs, each for the chosen target objectives**



Quadratic approximation for small amount of variables

0.1 - with start design
→ Local search





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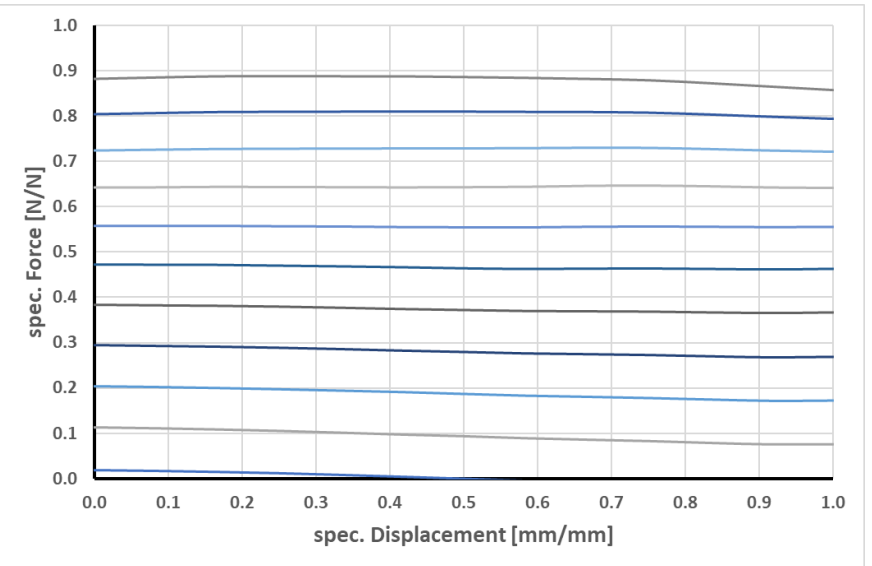
What is the conclusion?

Results

- Sensitivity analysis gives understanding of system behaviour
- Influence on responses depends on input parameter range
- Multi-objective optimization allows manual choice objectives and constraints
- Serves as start designs and enables local search for single-objective optimization
- Systematic approach guarantees reliable results.
- Increased force by about 35%
- Force-displacement curves show only current dependencies



Perspective

- Comparison of simulation results with measured data used as reference curves
- Model calibration

Thank you for your attention

Any questions?

Special Thanks to:

Mr. Markus Stokmaier for support