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WOST2019

APPLICATION WORKSHOPS

COSTS & FUNCTIONAL OPTIMIZATION

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Cost and Function Optimization
Introduction

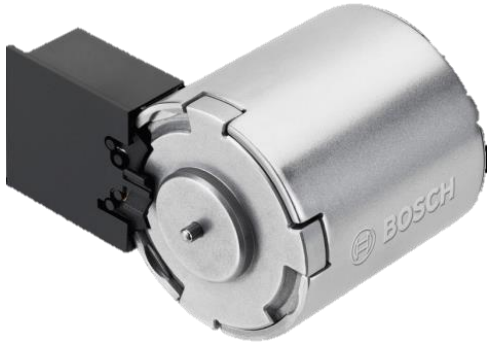
Linear Force Solenoid (LFS)

Product Description

- LFS for automated transmissions with direct shift control

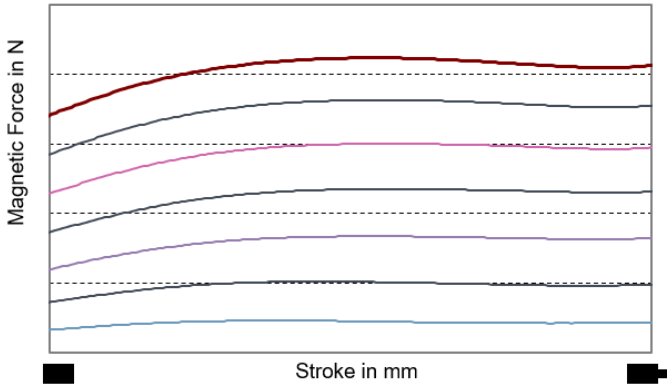
Specification

- Current range: 1.2 A
- Dimension: Ø 32.5 mm
- Stroke range: 2.2 – 3.5 mm
- Force Level: up to 25 N



Customer Requirement

Characteristic Curves



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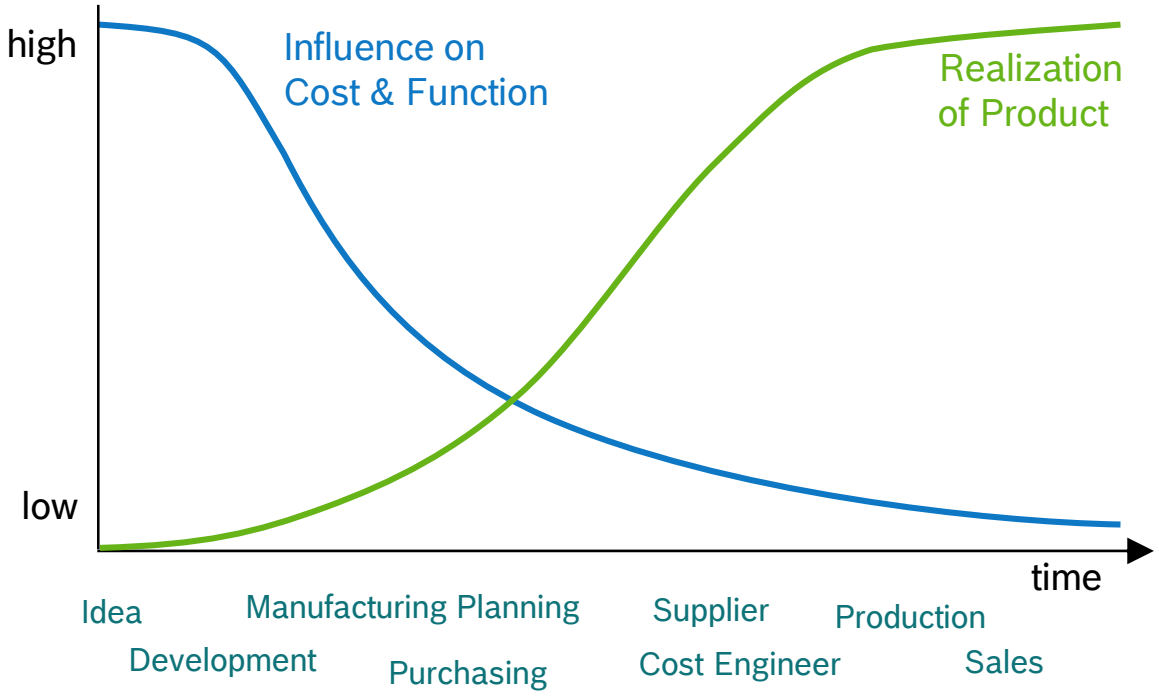
Cost and Function Optimization
Introduction

Dilemma of Product Development



Advantages

- Reduce product costs
- Reduce time to market
- Create new design approaches
- Front loaded simultaneous engineering

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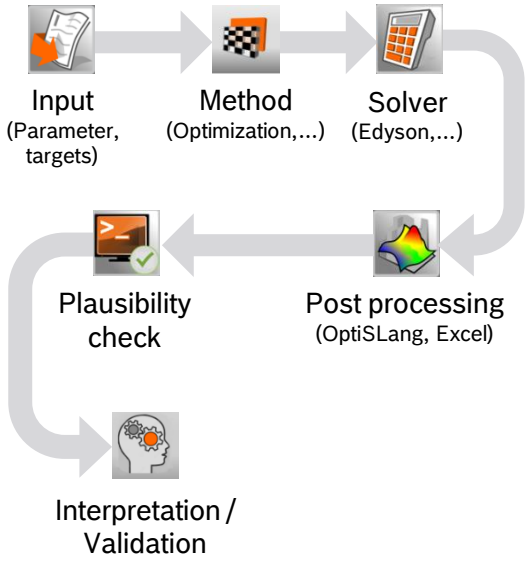
Cost and Function Optimization
Innovation Hypothesis

State of the Art – Function Optimization

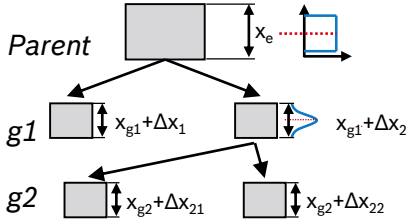
Workflow



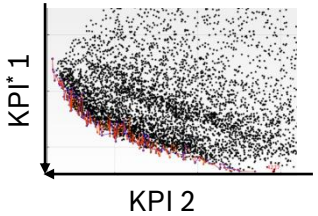
Evolutionary Algorithm (EA)

An evolutionary development process creates a pareto front of the best designs

Variation of design parameters with EA

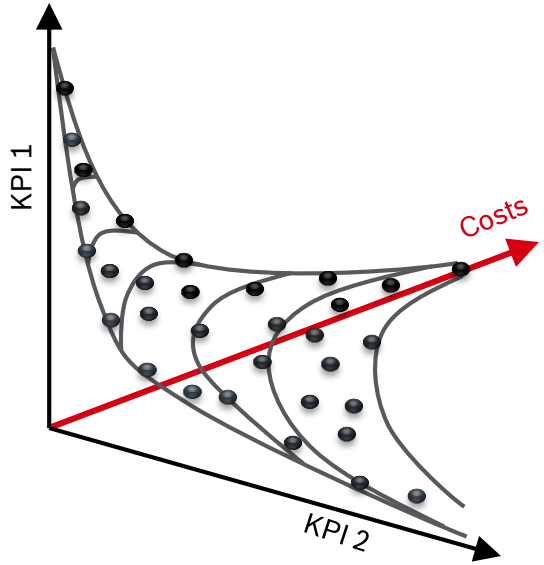


Result: Optimized technical behavior for contrary KPI's



Cost and Function Optimization

Cost function extends parameter search space (third axis).



* KPI: key performance indicator

Enhance function optimization with cost optimization to develop competitive products in shorter time.

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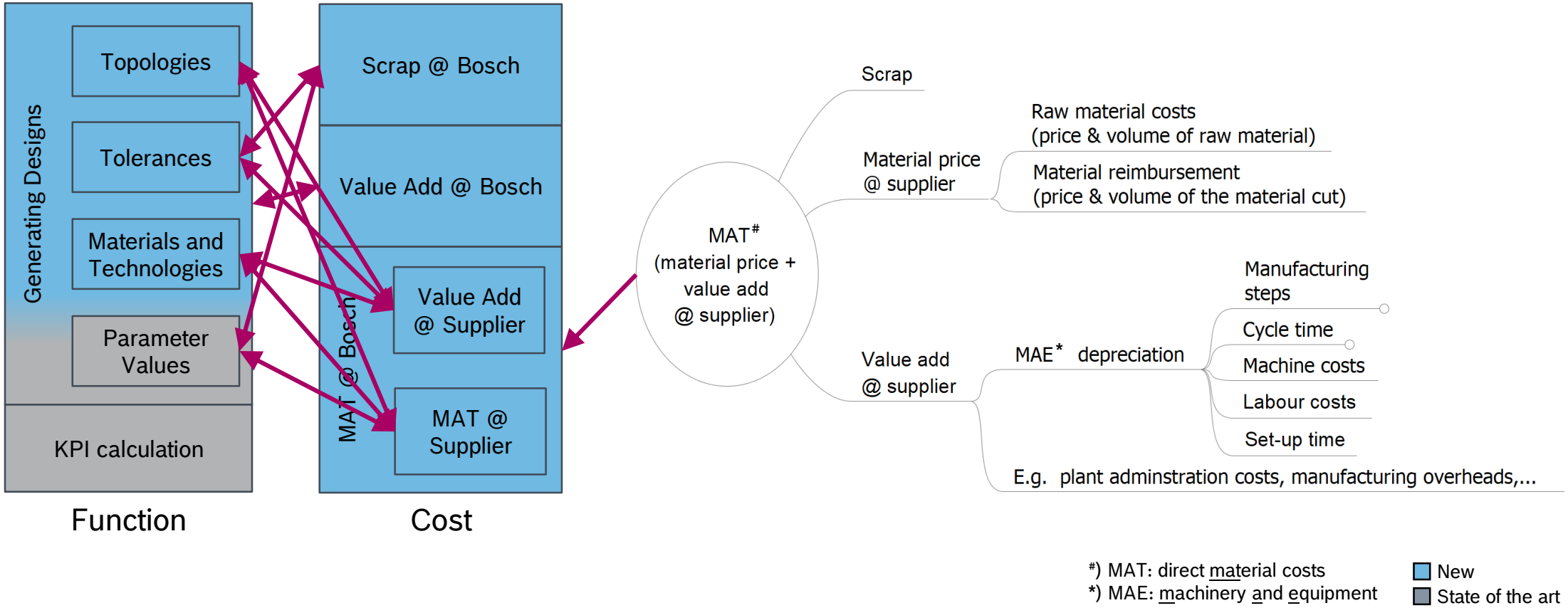
Cost and Function Optimization

Requirements to Set Up a Cost and Function Optimization



#) MAT: direct material costs
*) MAE: machinery and equipment

New
State of the art

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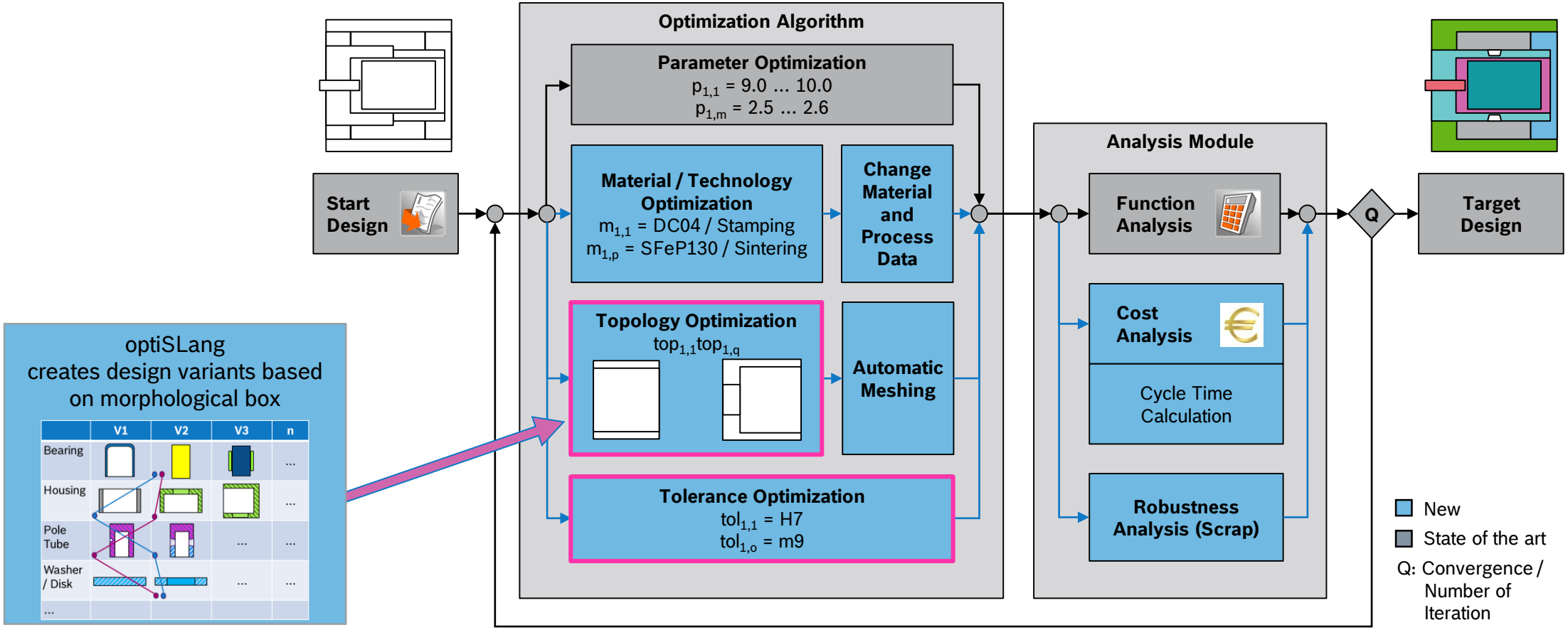
Cost and Function Optimization
Workflow



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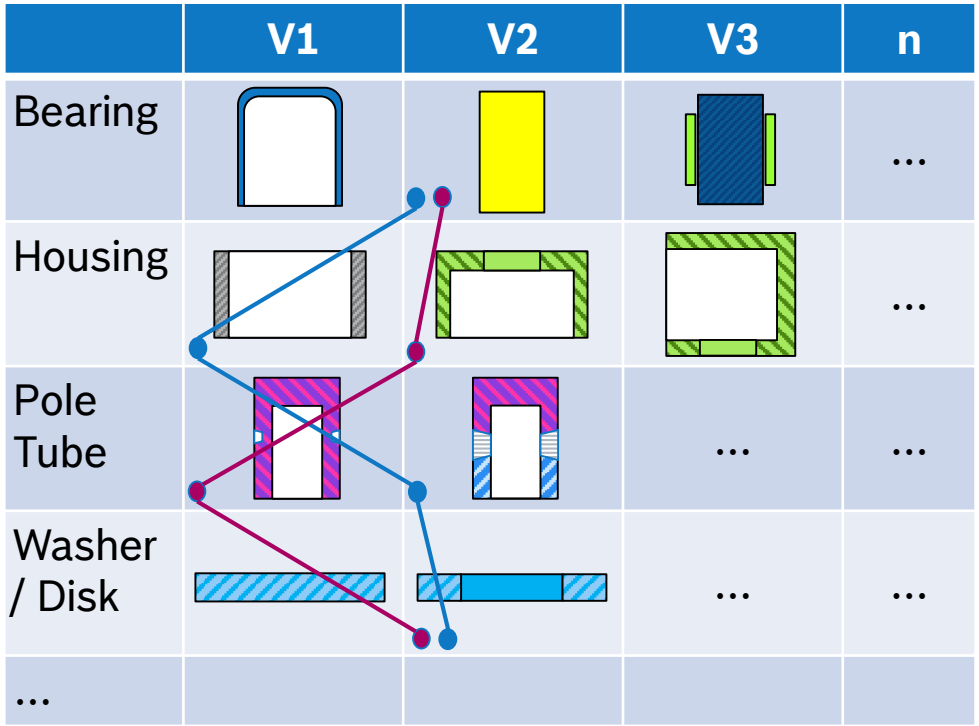
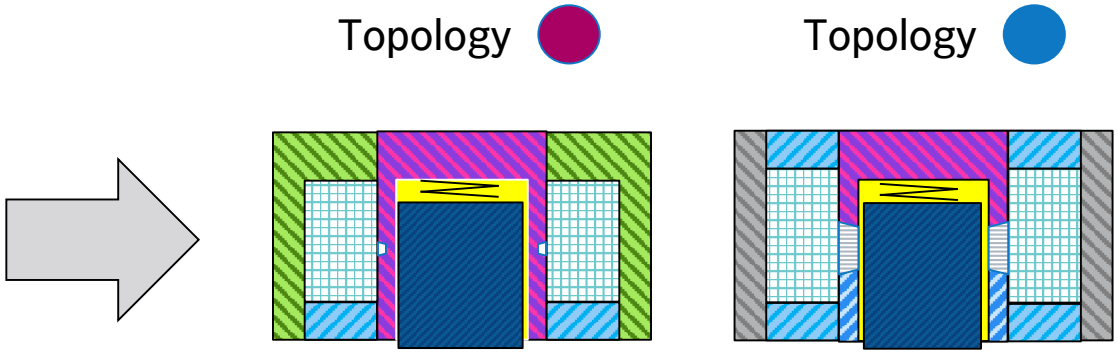
Cost and Function Optimization

Topology Optimization – Morphological Box

1. Describe possible parts of the solenoid via morphological box

2. Automatic derivation of new designs based on morphological box





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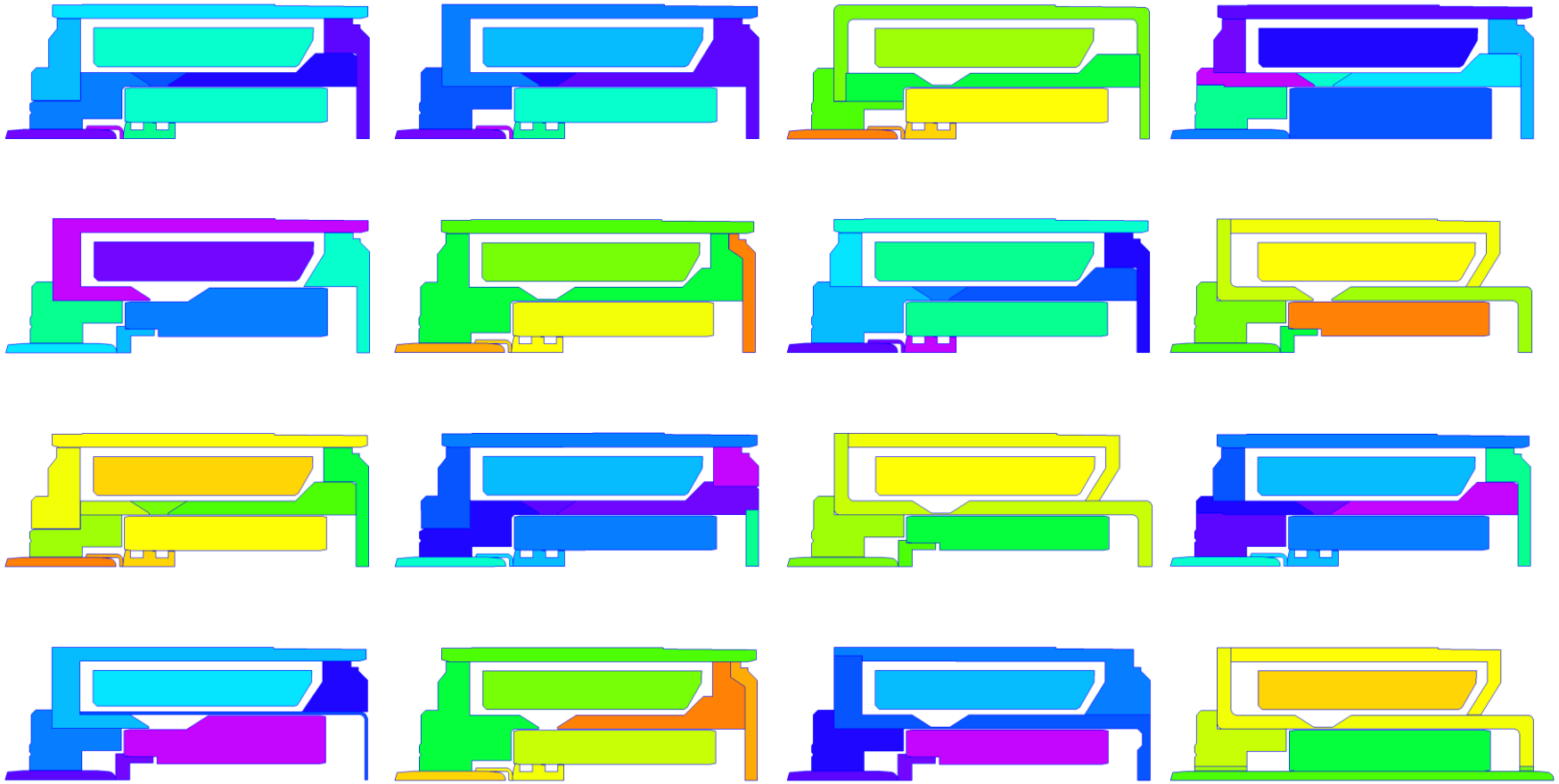
Cost and Function Optimization

16 Input Variants for Topology Optimization

Boundary conditions:

- Outer dimensions fixed, inner dimensions free
- Comparison includes different materials, tolerances and topologies of components

→ More then 180 topologie variants possible



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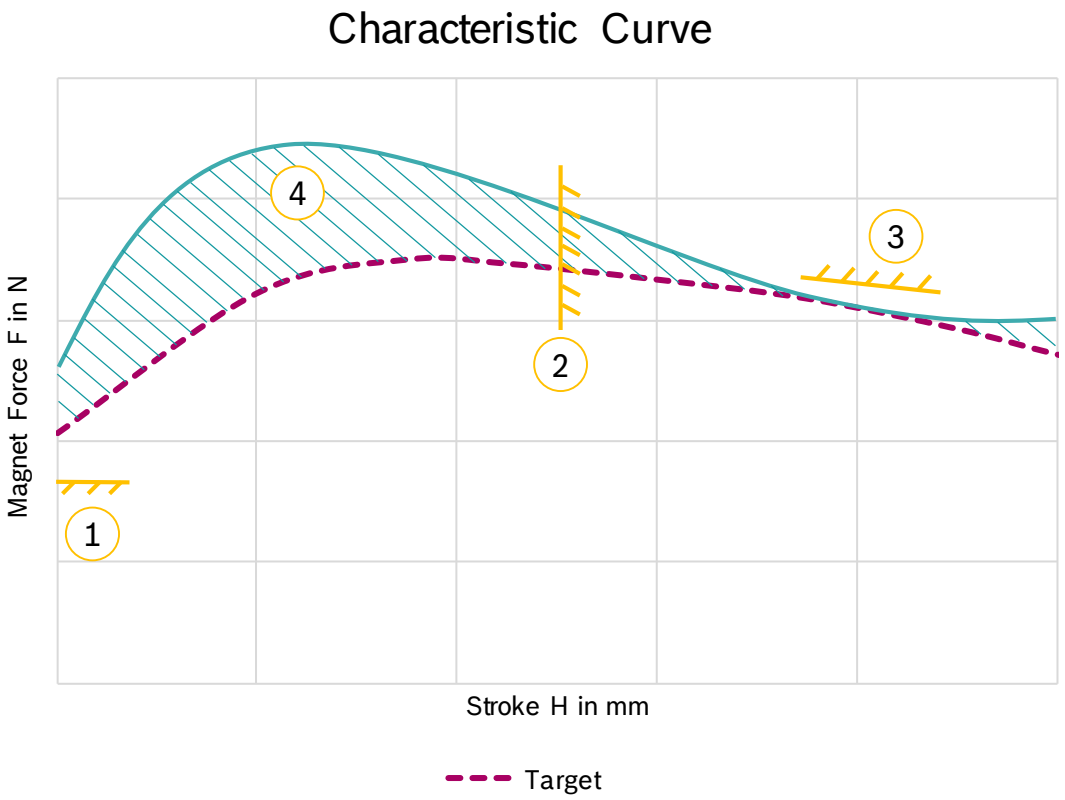
Cost and Function Optimization
Optimization Targets

Constraints

1. $F_{0\,mm} \geq F_1$
2. $H_{Stützstelle} \leq H_1$
3. Curve increasing min. $-c_1$ N/mm

Objectives

4. Min form deviation
5. Min costs



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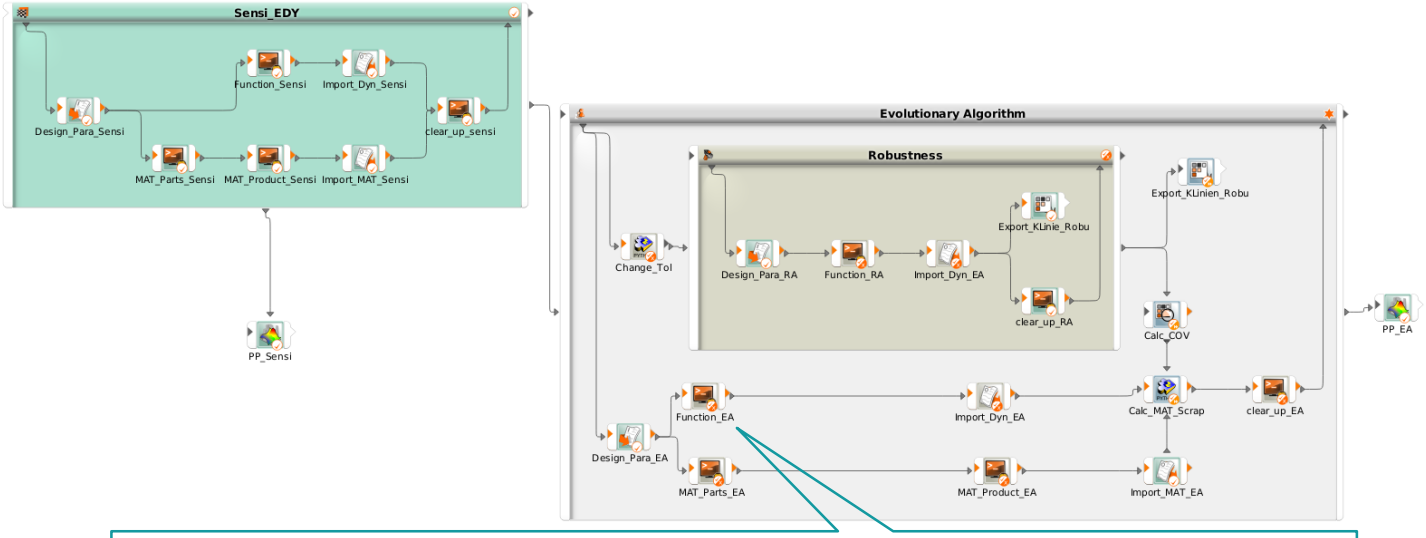
Cost and Function Optimization
Workflow – Realized in optiSLang

Realized workflow of the cost and function optimization includes

- Sensitivity analyse (4000 designs)
- Evolutionary algorithm
- Integrated robust design analysis
- Python scripts integrated via bash commands
- Duration of simulation ~38 h
- 99 variables
- 3 objectives and 9 constraints




```
# copy data or create link
cp ${CALCINPUT}/${EDY}.ini .
cp ${CALCINPUT}/${EDY}.geo .
cp ${CALCINPUT}/${EDY}.py .

# starts change geo-, ini-file and calculate coil
dos2unix ${EDY}.ini
dos2unix ${EDY}.geo
subbin -t -r 00:05 -n 1 -i -N 1 -m 200M python ${CALCINPUT}/TOOLS/change_geo_v100.py Design_Parameters.txt ${EDY}
subbin -t -r 00:05 -n 1 -i -N 1 -m 200M python ${CALCINPUT}/TOOLS/change_coi_v100.py Design_Parameters.txt ${EDY} ${FILE}
subbin -t -r 00:05 -n 1 -i -N 1 -m 200M python ${CALCINPUT}/TOOLS/change_ini_v100.py Design_Parameters.txt ${EDY}
```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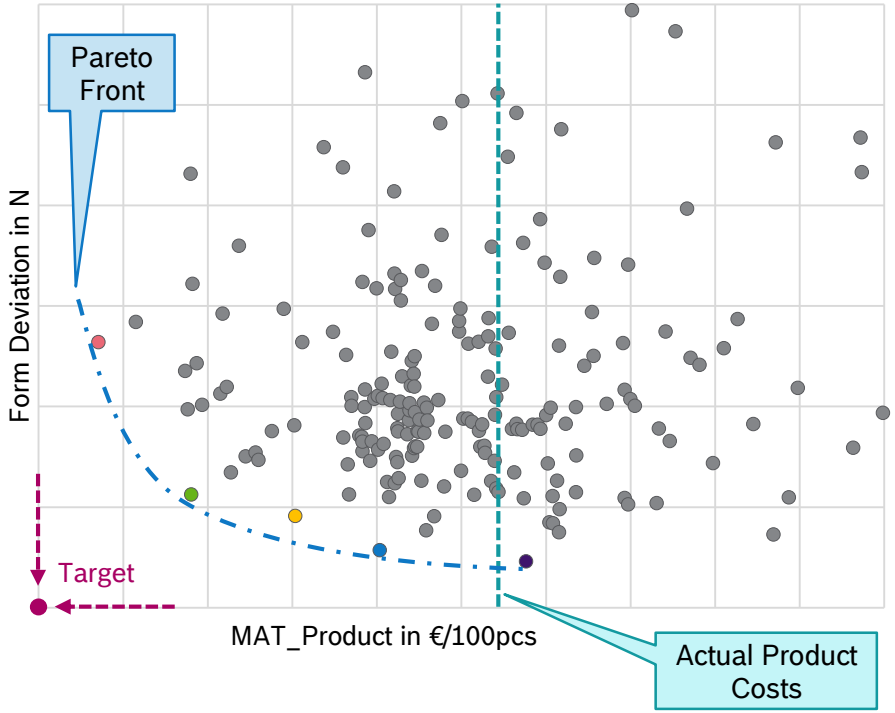
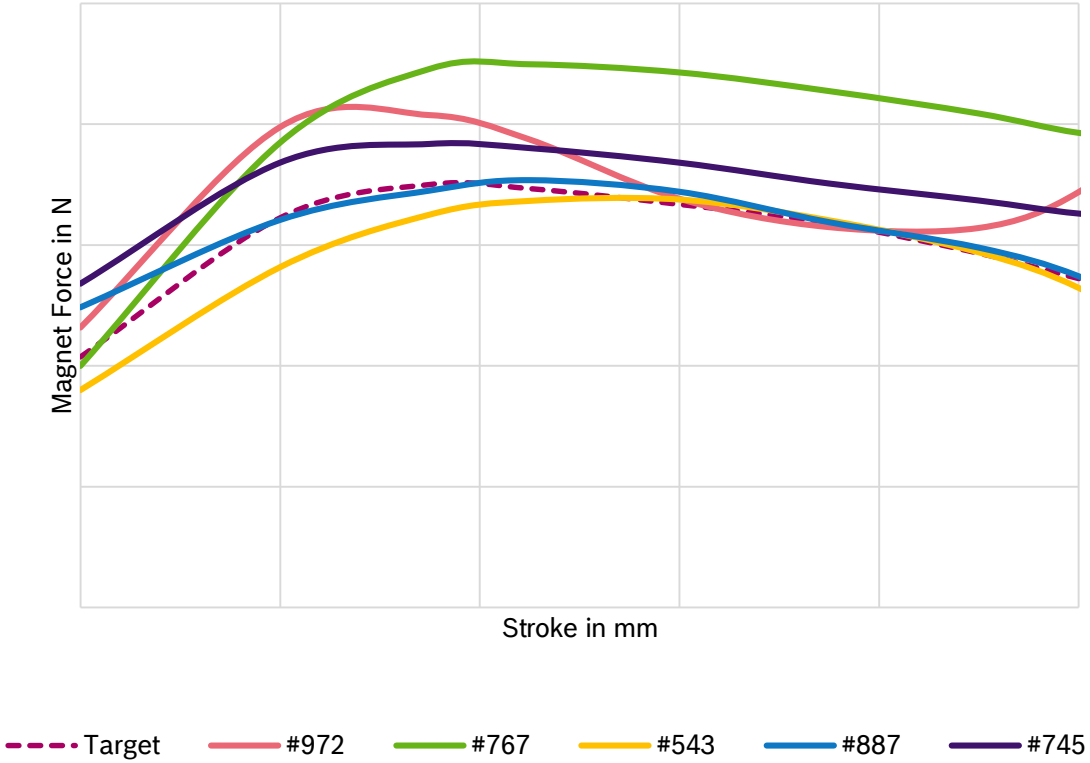
Cost and Function Optimization
Topology Optimization – Evaluation

Form Deviation Over MAT



Characteristic Nominal Curves



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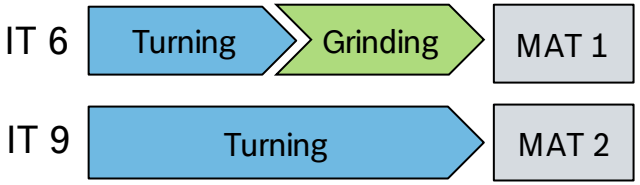
Cost and Function Optimization
Tolerance Optimization – Details

MAT – Calculation

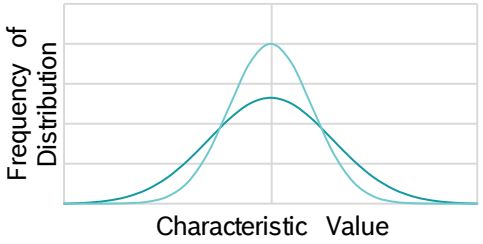
1. Create new designs with different dimensions and tolerance classes

2. Automatic manufacturing steps selection based on given dimension and tolerance class



Robustness Analysis

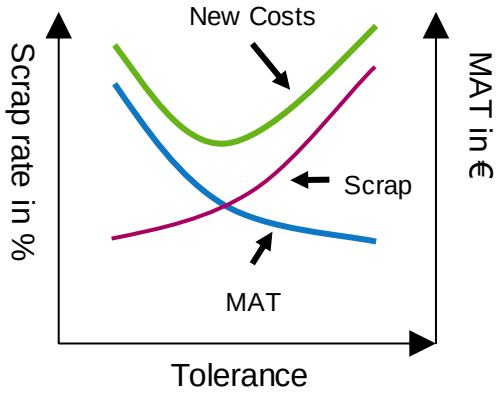
3. Automatic adjustment of individual dimension range based on given tolerance class



4. Run robust design analysis for each design

Component Costs

5. Calculate new component costs based on scrap costs and MAT costs



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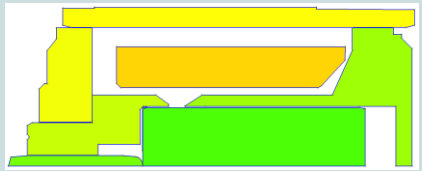
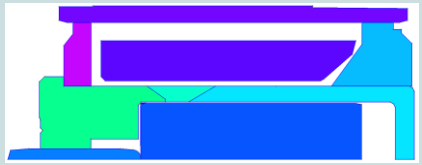
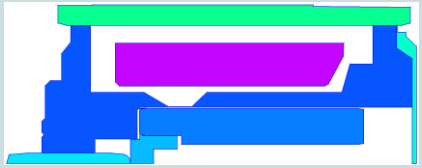
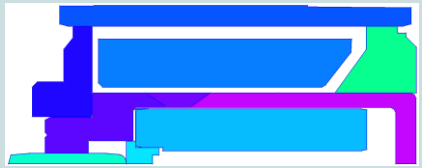
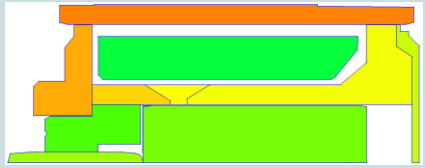
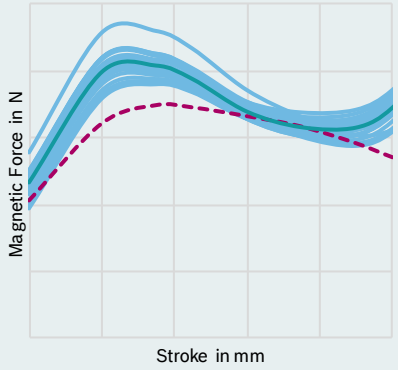
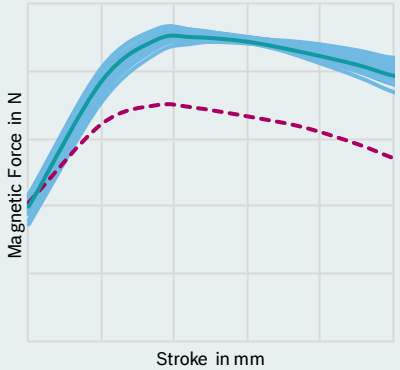
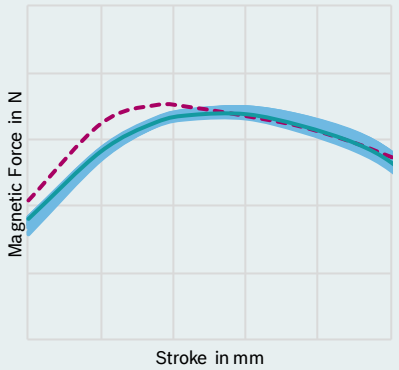
Cost and Function Optimization
Comparison of Solutions

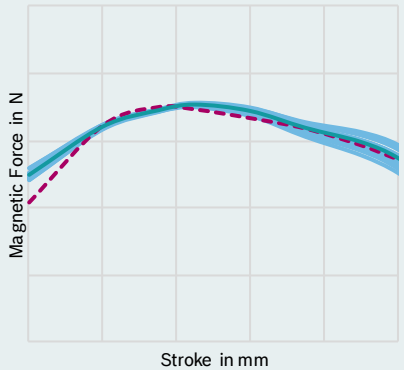
# 972	# 767	# 543	# 887	# 745
• MAT: -28 % • Form Deviation: 25 %	• MAT: -21 % • Form Deviation: 10 %	• MAT: -13 % • Form Deviation: 8 %	• MAT: -7 % • Form Deviation: 5 %	• MAT: +5 % • Form Deviation: 4 %

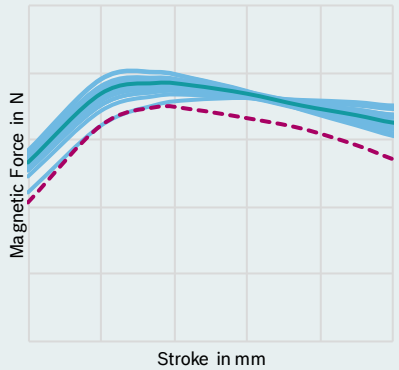
















→ Generates Designs which fulfil the requirements

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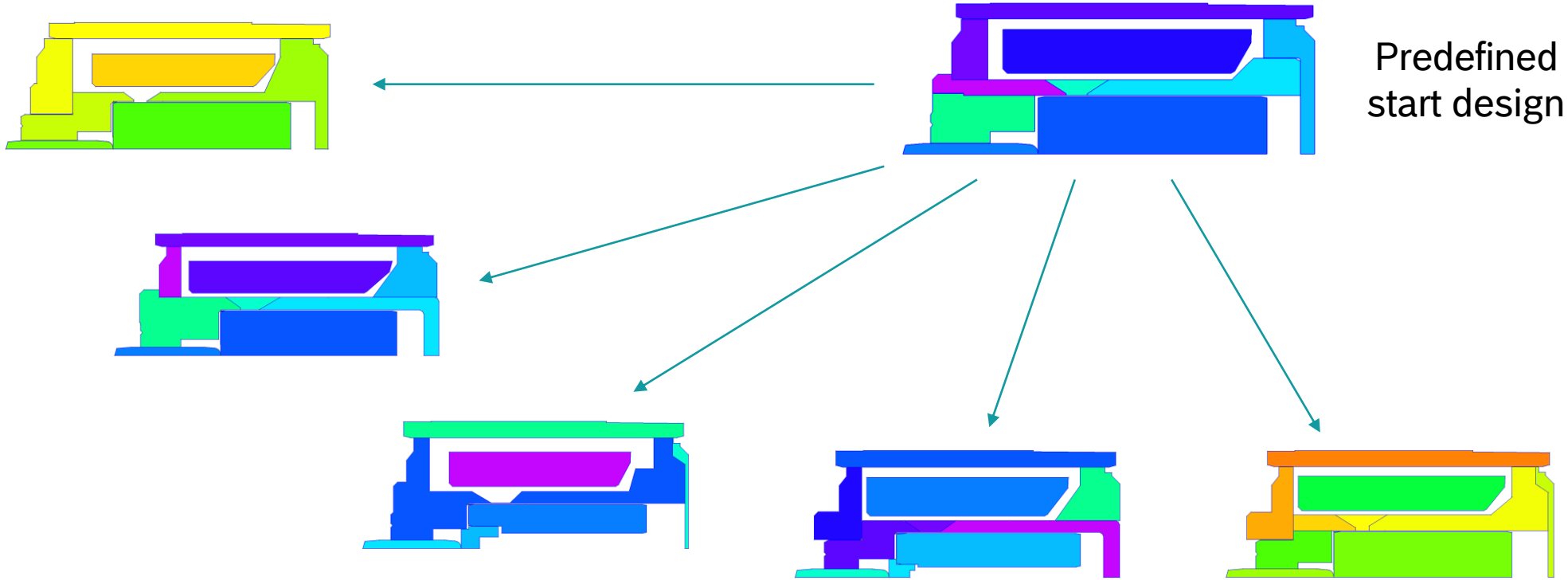
Cost and Function Optimization
Comparison of Solutions



→ Method generates new designs which are not predefined in the start designs

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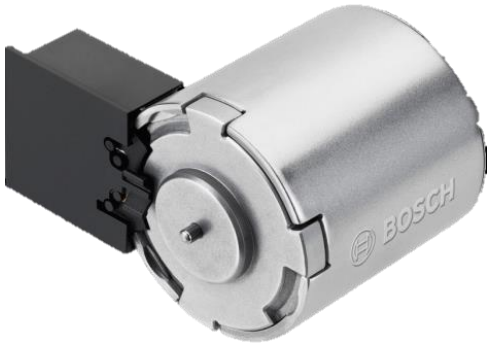
Cost and Function Optimization
Conclusion

- Proposed method identifies optimal designs regarding function and costs which
  - Fulfil requirements
  - Save money
  - In short time
- Individually adaptable
  - Manufacturing processes
  - Products (proportional magnet, e-machine,…)
- Initial use in actual projects



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