Mathematical Optimization of Clamping Processes in Car-Body Production

12. Weimarer Optimierungs- und Stochastiktage 2015
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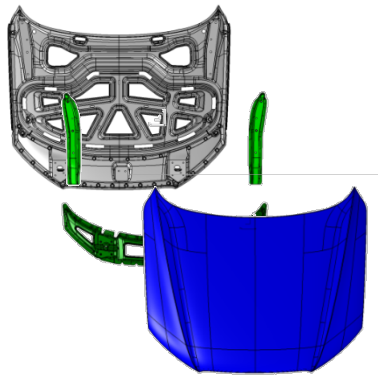
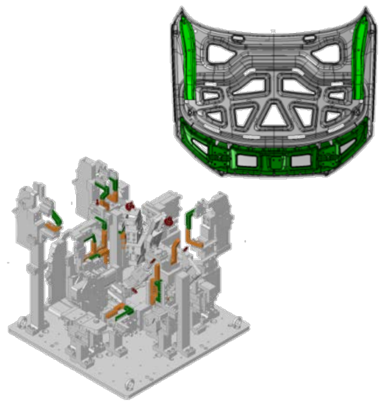
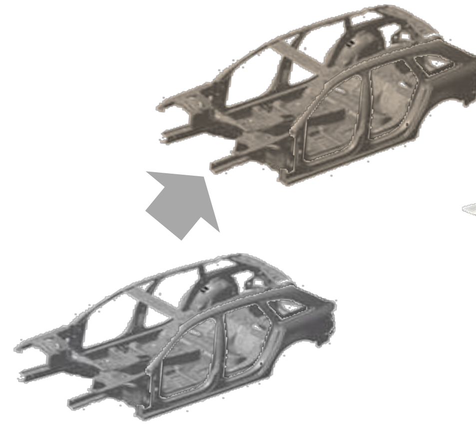
Introduction

Overview Car Body Process



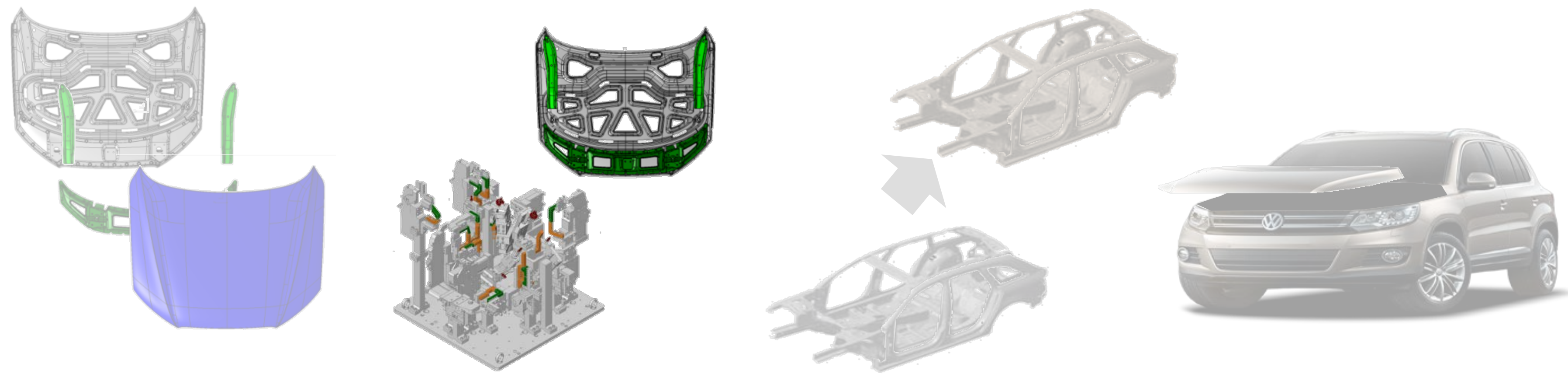




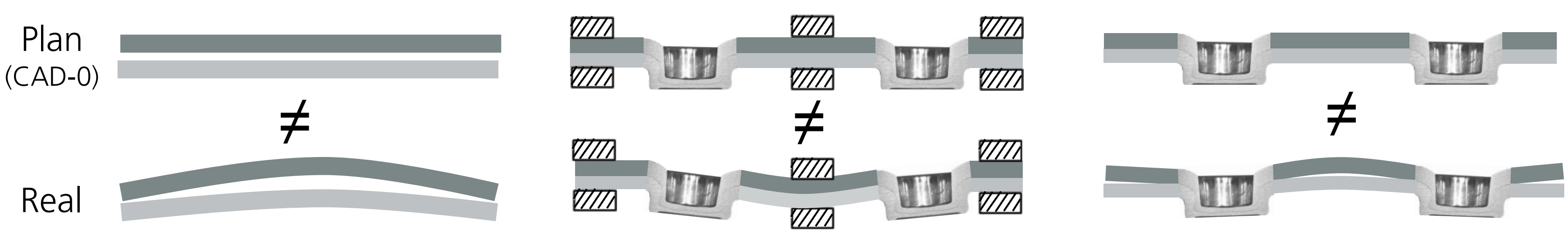
Press Shop → Assembling → Painting & Oven → Mounting

Introduction

Overview Car Body Process



Press Shop → **Assembling** → Painting & Oven → Mounting



single parts out of tolerance

deformed clamping und joining

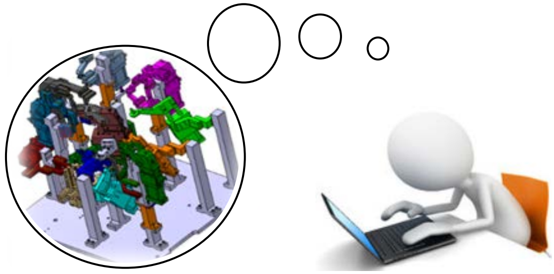
assembly in tolerance

Problem

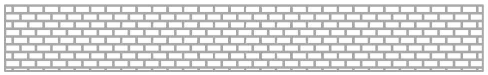
Actual Ramp-up Process

- planning process has high influence on costs during realization
- adjustment of fixture in cost and time intensive experience based optimisation loops
- processes are mostly separated

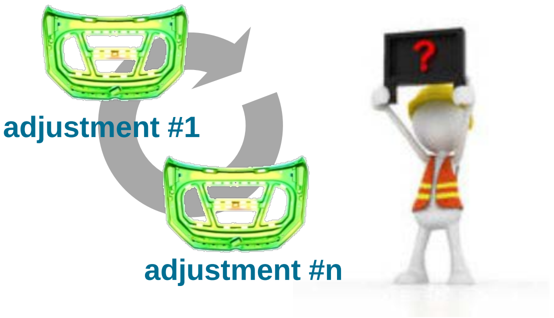
Ramp-up Process



design process



processes mostly separated



adjustment loops during realization

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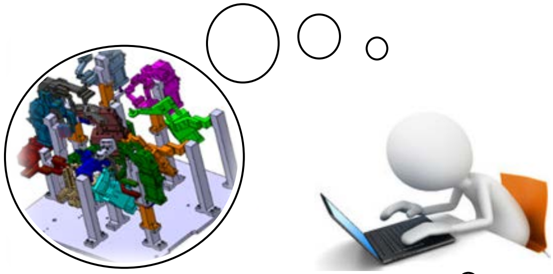
Destination

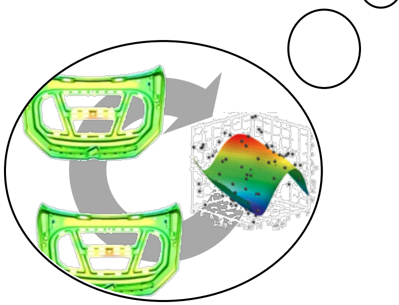
Ramp-up Process in Future

- planning process is numerically supported
- analysis of cause-and-effect-relationship between fixture adjustment and tolerance effect before realization
  →possible traps are known bevor realization
- during realization less optimization loops are needed
  → significant reducing of time and costs

Ramp-up Process



design process



virtual design check

reduced time/cost during realization

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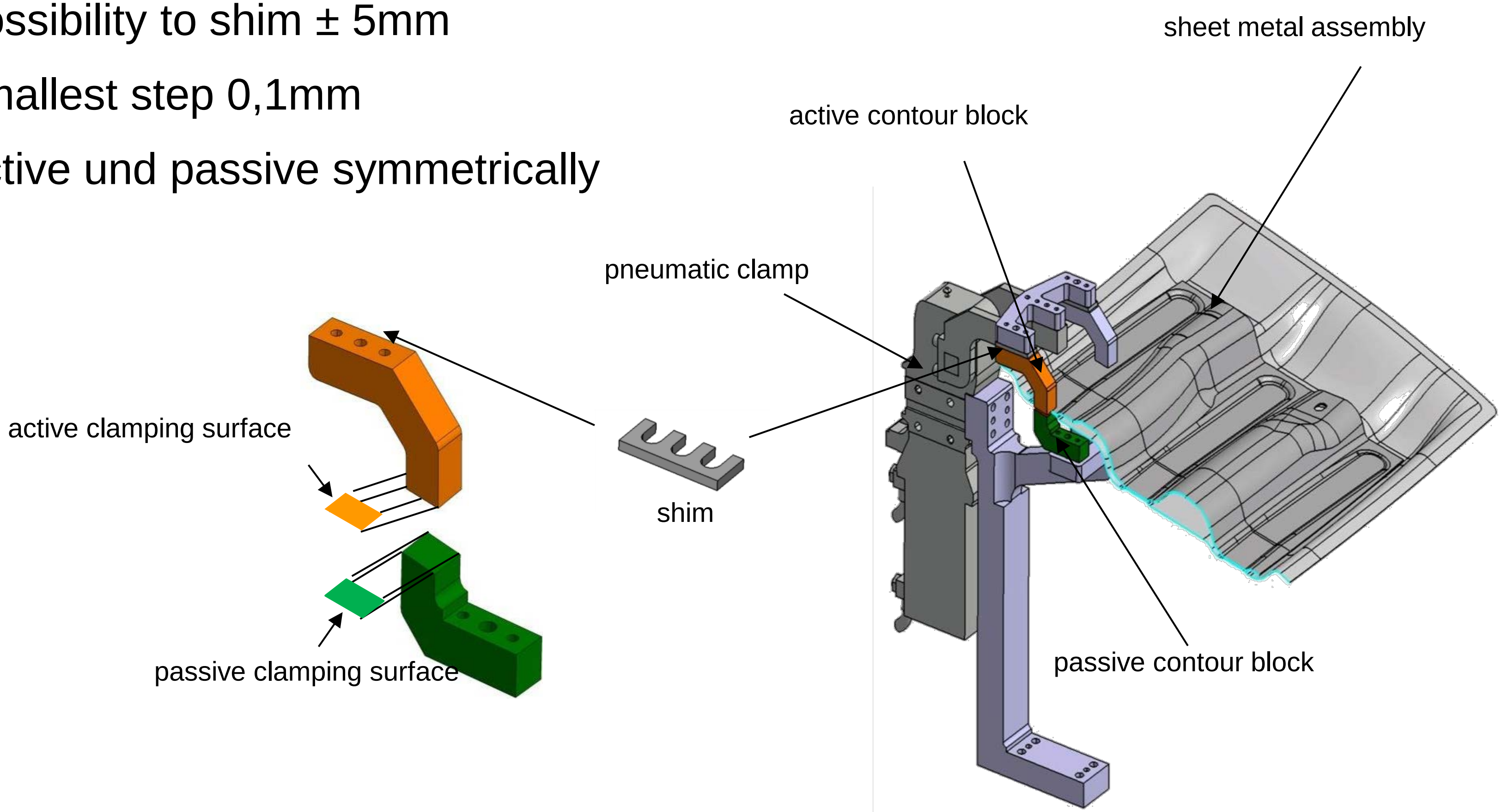
State of the Art

Assembly Fixture

- adjustment by using shim
- possibility to shim ± 5mm
- smallest step 0,1mm
- active und passive symmetrically



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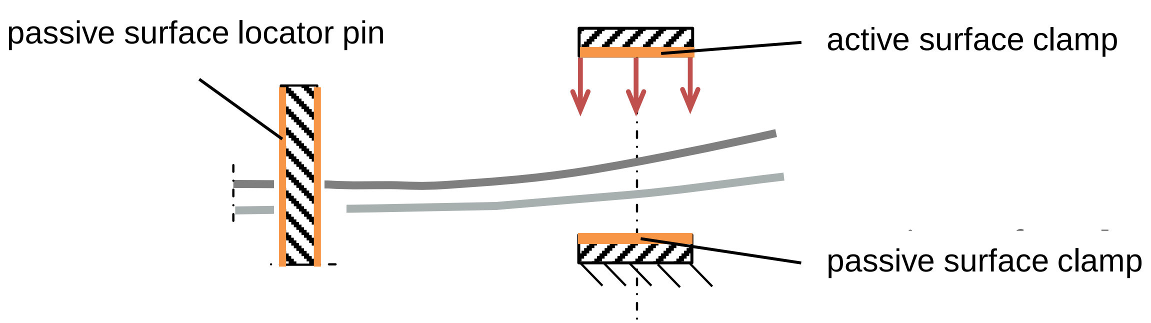
State of the Art

Numerical Prognosis In Assembly Processes

- solver ESI PamStamp 2G
- shell based simulation
  → active und passive surfaces are perfectly rigid
  → elastically/plastically deformable components represented by shells
- distortion caused by joining represented by local-global approach using mechanical equivalent loads
- single parts are digitalized and remeshed
- Stiffness of fixture represented by max. force of clamps

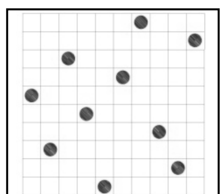
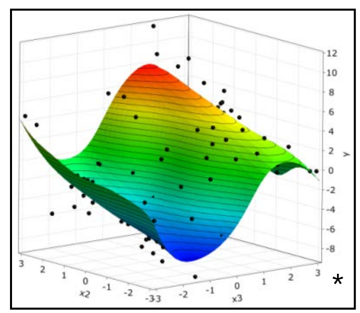


Optimization

Overview

- analyse the Design Space by choosing a suitable DoE-Scheme
- generate a fitting Metamodel

Analysing the design space:

Input Parameter	Design of Experiment	Metamodell	Objective Definition
Clamp 1 . . . Clamp 8	 Solver: PamStamp	 *	Deviation to CAD-0
Shim Adjustment	Sensitivity Analysis	Regression Analysis	Tolerance

* Quelle: Dynardo

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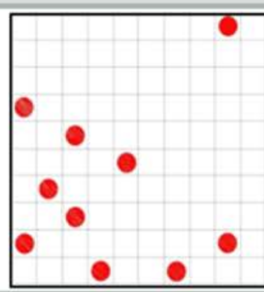
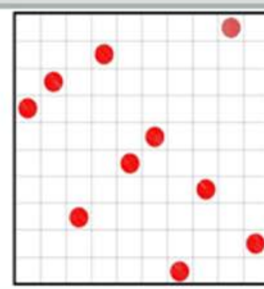
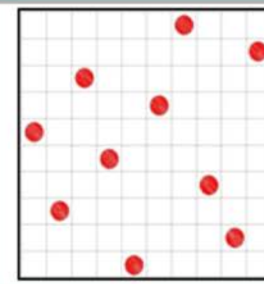
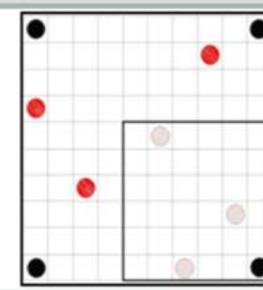
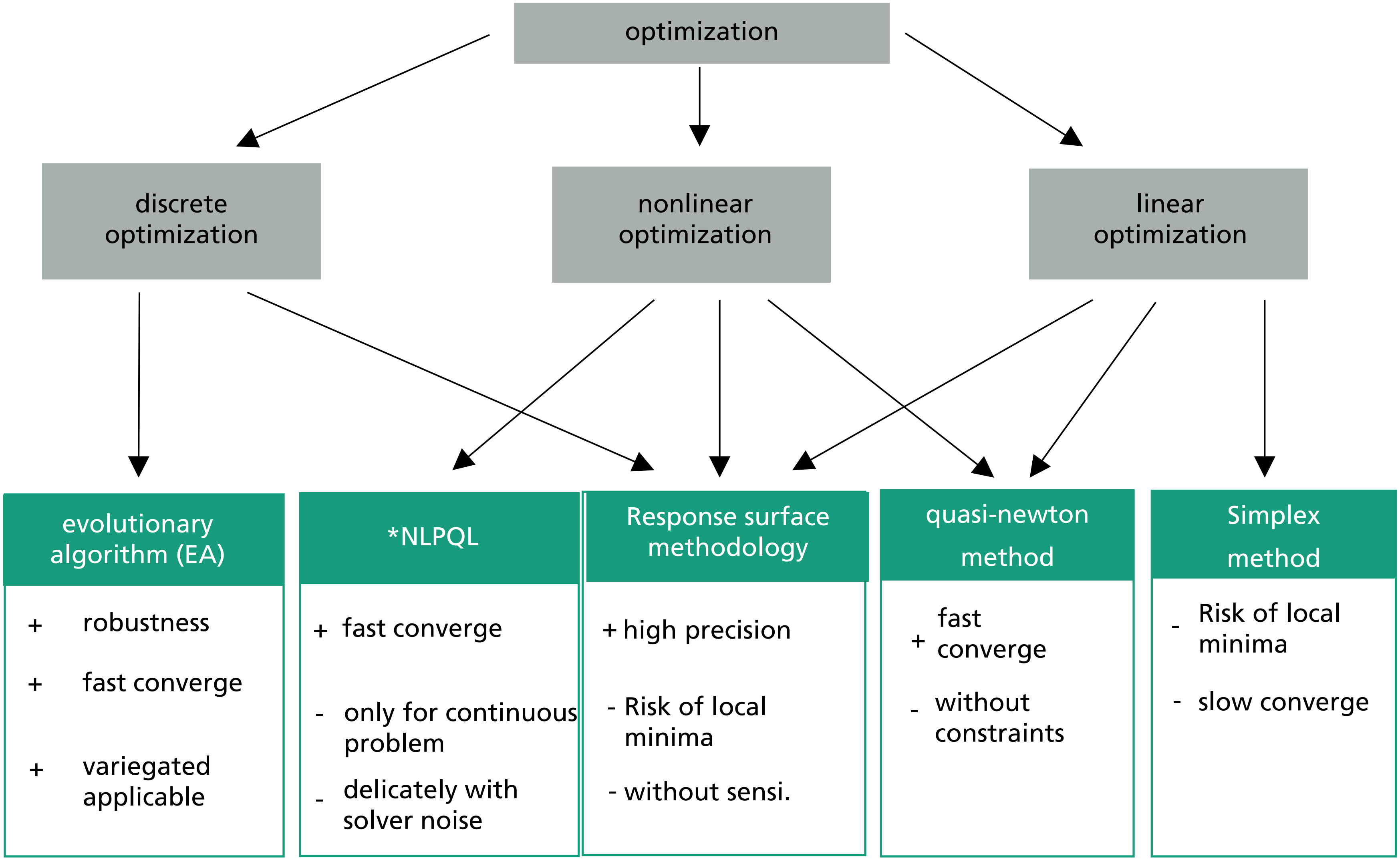
Chosen Algorithms

Sensitivity

	Monte Carlo Simulation	Latin Hypercube Sampling	Advanced Latin Hypercube Sampling	Boundary and Best Neighbor Sampling
Sampling scheme				
Number of samples	High	Small	Small	Small
Advantage		• reduced correlation • small number of samples	• no correlation • small number of samples	• small number of samples
Disadvantage	• strong input correlation	• low input correlation possible		• strong input correlation • risk of local extrema

Chosen Algorithms
Optimization



*NLPQL – Nonlinear Programming by Quadratic Lagrangian

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Chosen Algorithms

Optimization

optimization

discrete problem

discrete optimization

nonlinear optimization

linear optimization

high dimensional problem with constraints

evolutionary algorithm (EA)	*NLPQL	Response surface methodology	quasi-newton method	Simplex method
+ robustness	+ fast converge	+ high precision	+ fast converge	- Risk of local minima
+ fast converge	- only for continuous problem	- Risk of local minima	- without constraints	- slow converge
+ variegated applicable	- delicately with solver noise	- without sensi.		

*NLPQL – Nonlinear Programming by Quadratic Lagrangian

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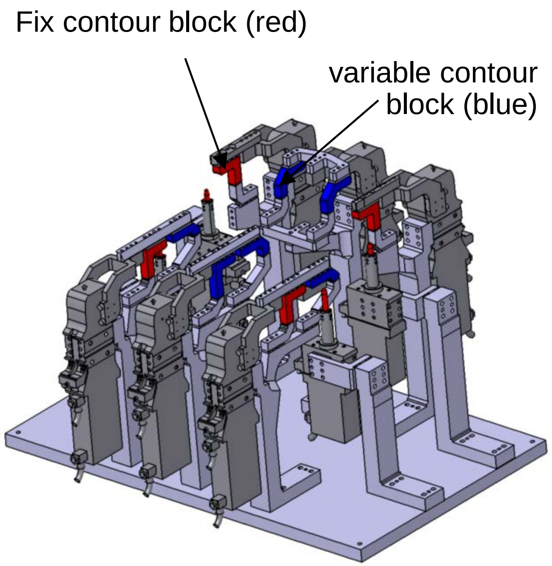
Setup

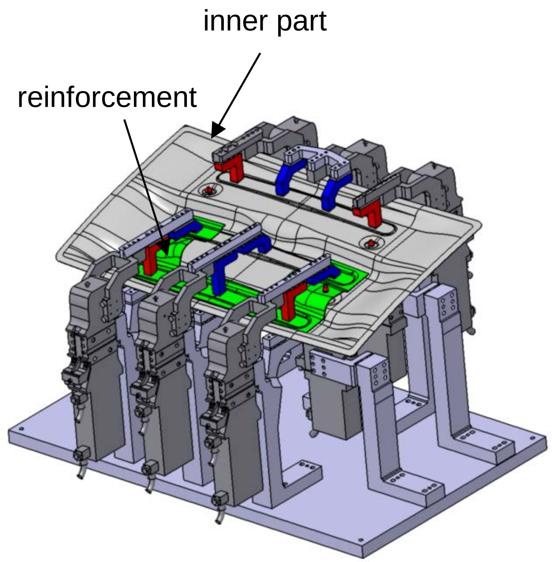
Analysed Parts And Devices

- Car body similar deep drawed single parts
- fixture in body construction standard
- 6 adjustable / 4 fix clamps

clamping device

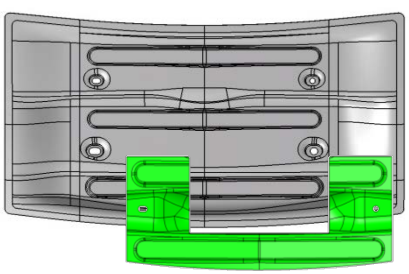


clamping device with assembly



material data (assembly)

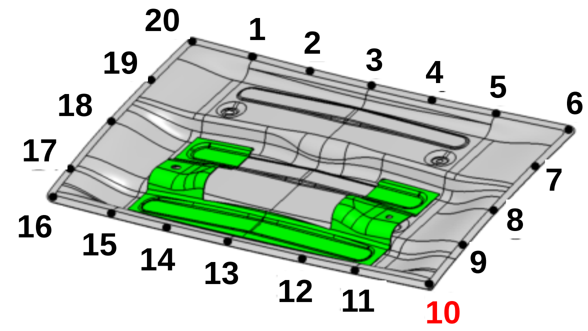
- reinforcement: 1.5mm (AA6181)
- inner part: 1.0 mm (AA6181)

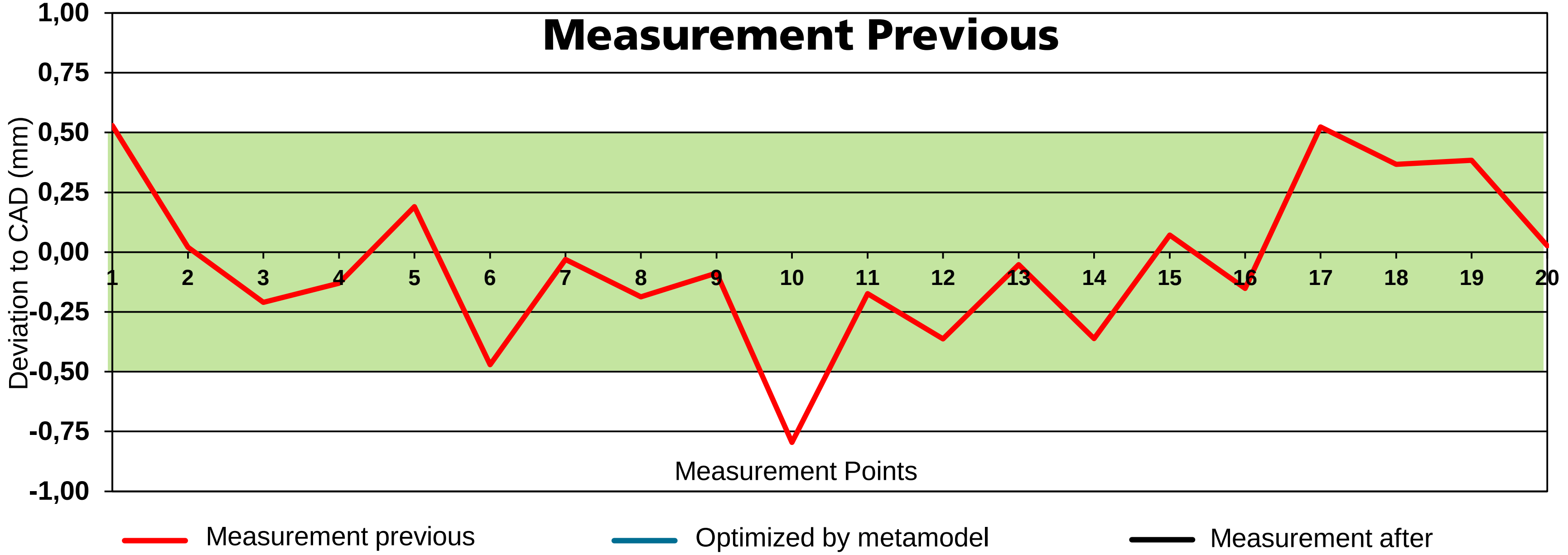


Compensation on Real Add-On Body Part

Compensation in MP10

- tolerance set to ±0.5mm
- measurement point 10 out of range





Compensation on Real Add-On Body Part

Compensation in MP10

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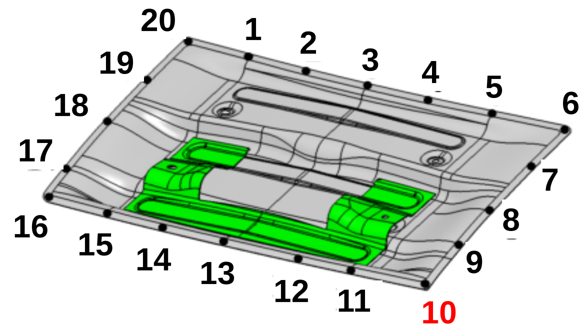
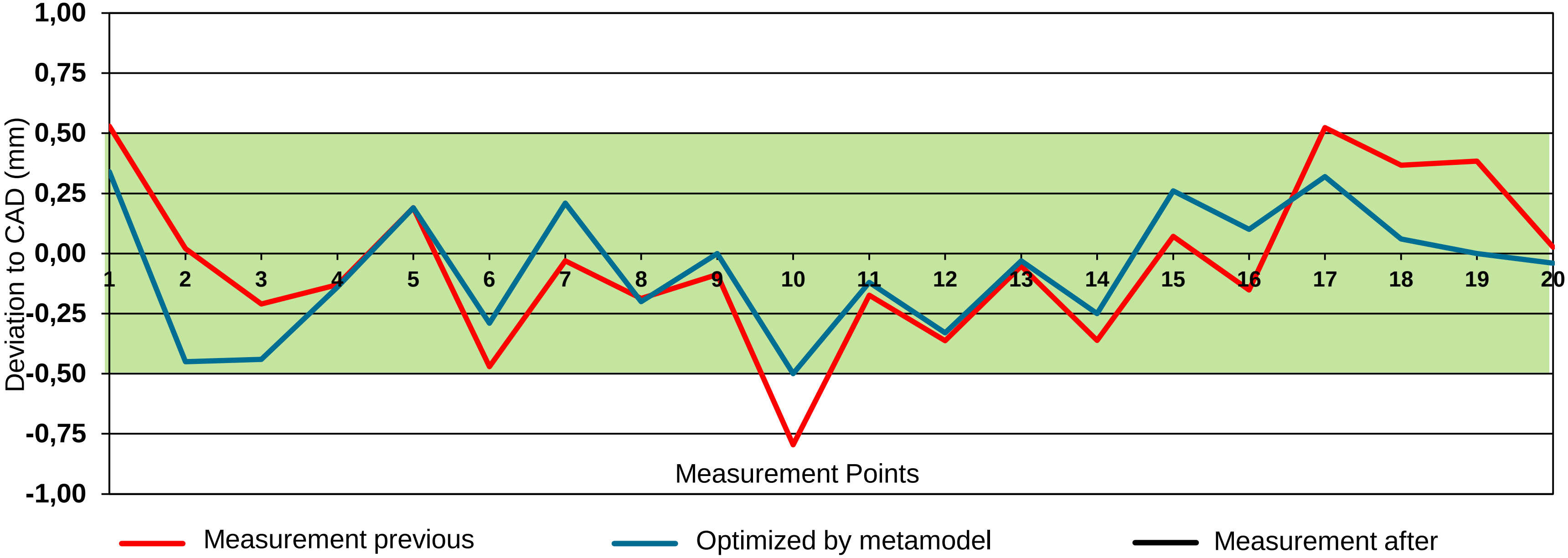
- measurement point 10 out of range
- after optimization into range





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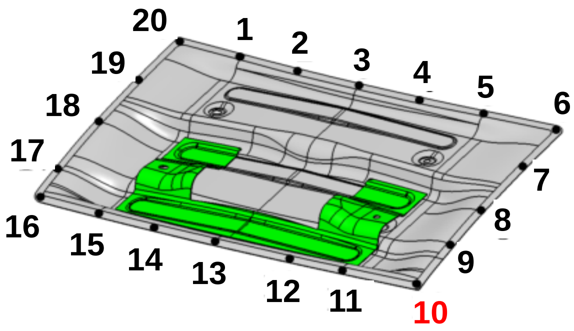

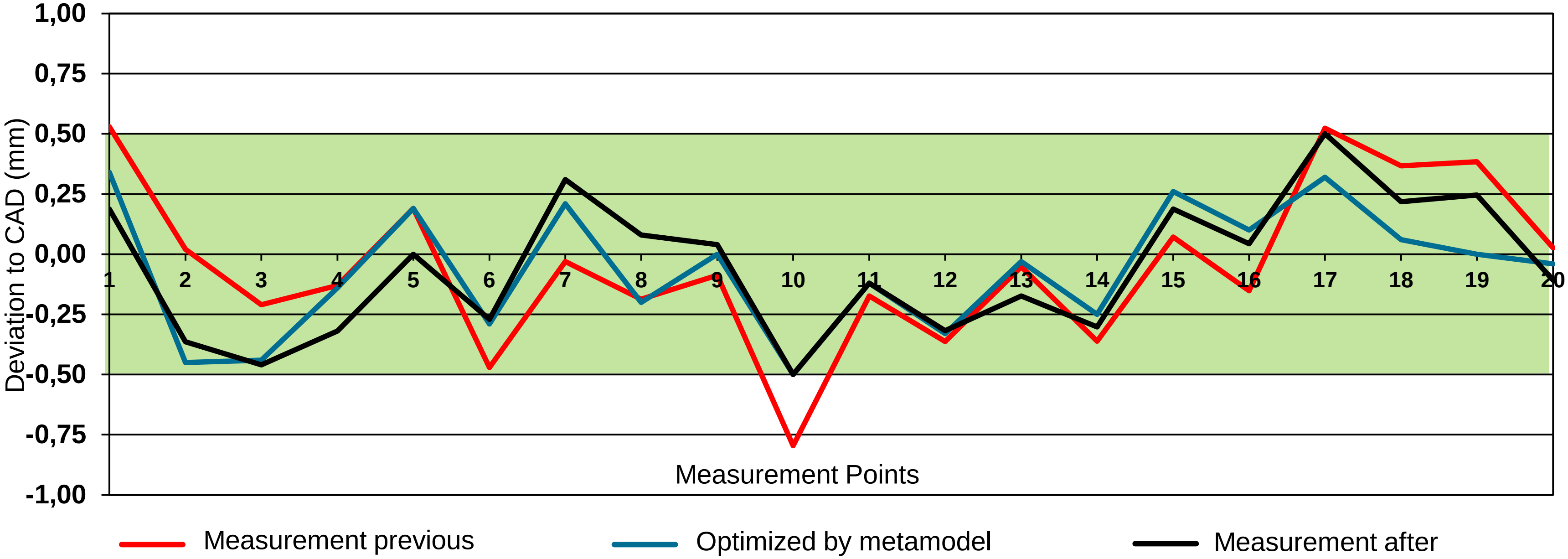

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Conclusion

- combination of mathematical optimization algorithm and FEM analysis is capable to forecast tolerance effects of fixture adjustments

- fist step to make adjustment process not longer only experience based is done

- next Steps

  → include complete stiffness of fixture and clamps
  → analyse prognoses capability based on CAD-Data
  → try out on real body parts

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Thank you for your attention