Headquarter Research and Technology

Introduction and first experiences with optimization tools within the Pierburg *DRIVE* product development process

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4th European HTC
Versailles October 28th – 29th, 2010

KOLBENSCHMIDT PIERBURG

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Rheinmetall AG

€ 3.4 bn Sales   19,750 Employees

Kolbenschmidt Pierburg AG

Leading automotive supplier of engine components and systems

Sales: € 1.5 billion

Employees: 10,300

Rheinmetall Defence

Leading European Defence company for ground forces technology

Sales: € 1.9 billion

Employees: 9,300

Fiscal year 2009

The six divisions

Kolbenschmidt Pierburg AG

Corporate Functions

Controlling + Finance | Research + Technology | IT | Human Resources

Legal | Corporate Development | Corporate Communications

KS Kolbenschmidt	KS Aluminium-Technologie	Pierburg	Pierburg Pump Technology	Motor Service	KS Gleitlager
Sales: € 466 m	Sales: € 119 m	Sales: € 392 m	Sales: € 293 m	Sales: € 185 m	Sales: € 126 m
Employees: 4,777	Employees: 931	Employees: 1,929	Employees: 1,240	Employees: 409	Employees: 994
Products: - Passenger car pistons - Commercial vehicle pistons - Piston modules - Large-bore pistons - MIR	Products: - Aluminum engine blocks - Final machining - Cylinder heads - Cast aluminum components	Products: - Air Management - Emission Control - Actuators - Solenoid Vales - Commercial Diesel systems	Products: - Oil pumps - Water pumps - Vacuum pumps	Products: - Automotive parts for engine repair and workshops - OES + SOE	Products: - Engine bearings - Dry bearings (Permaglide®) - Continuous casting

Fiscal year 2009

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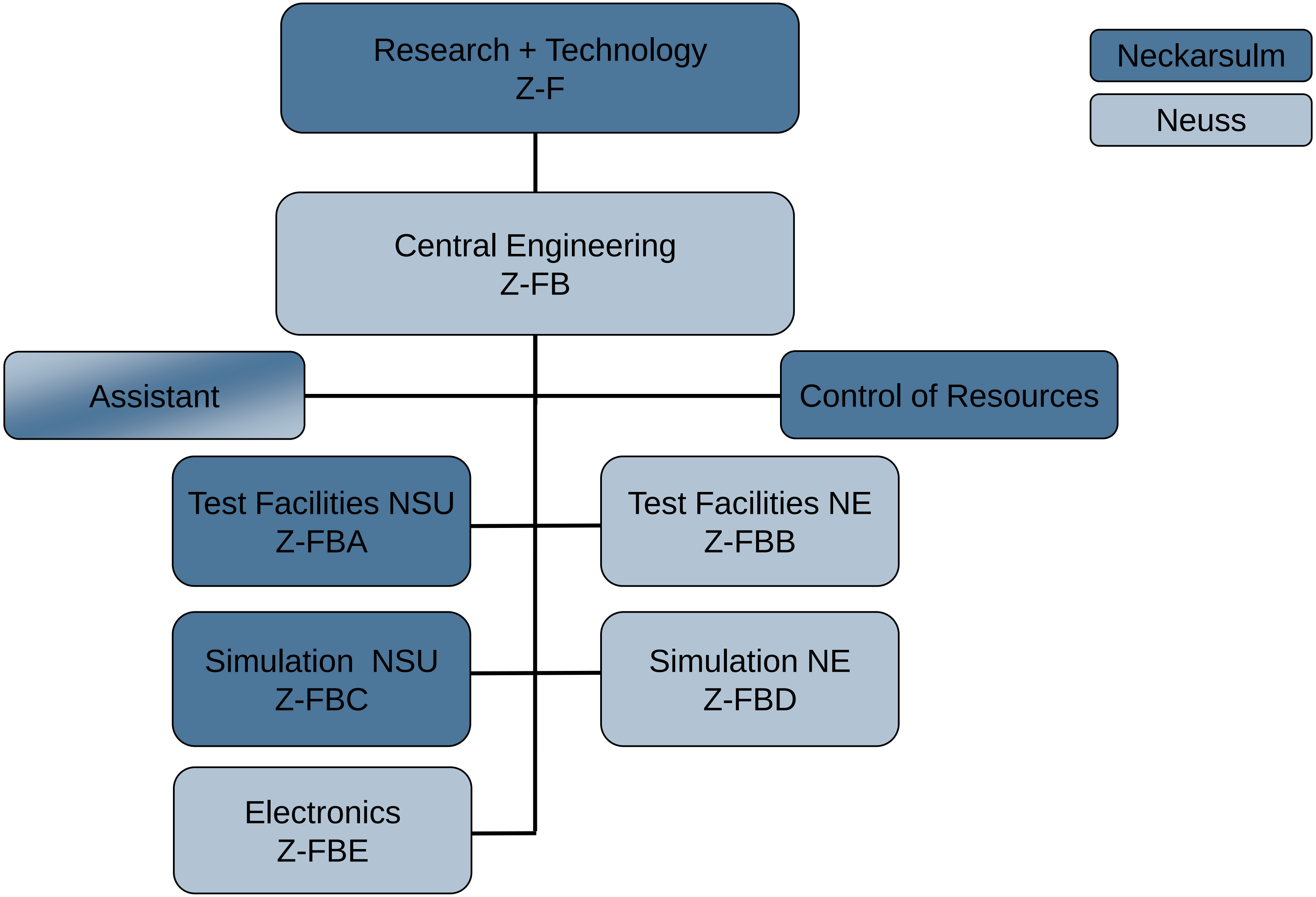
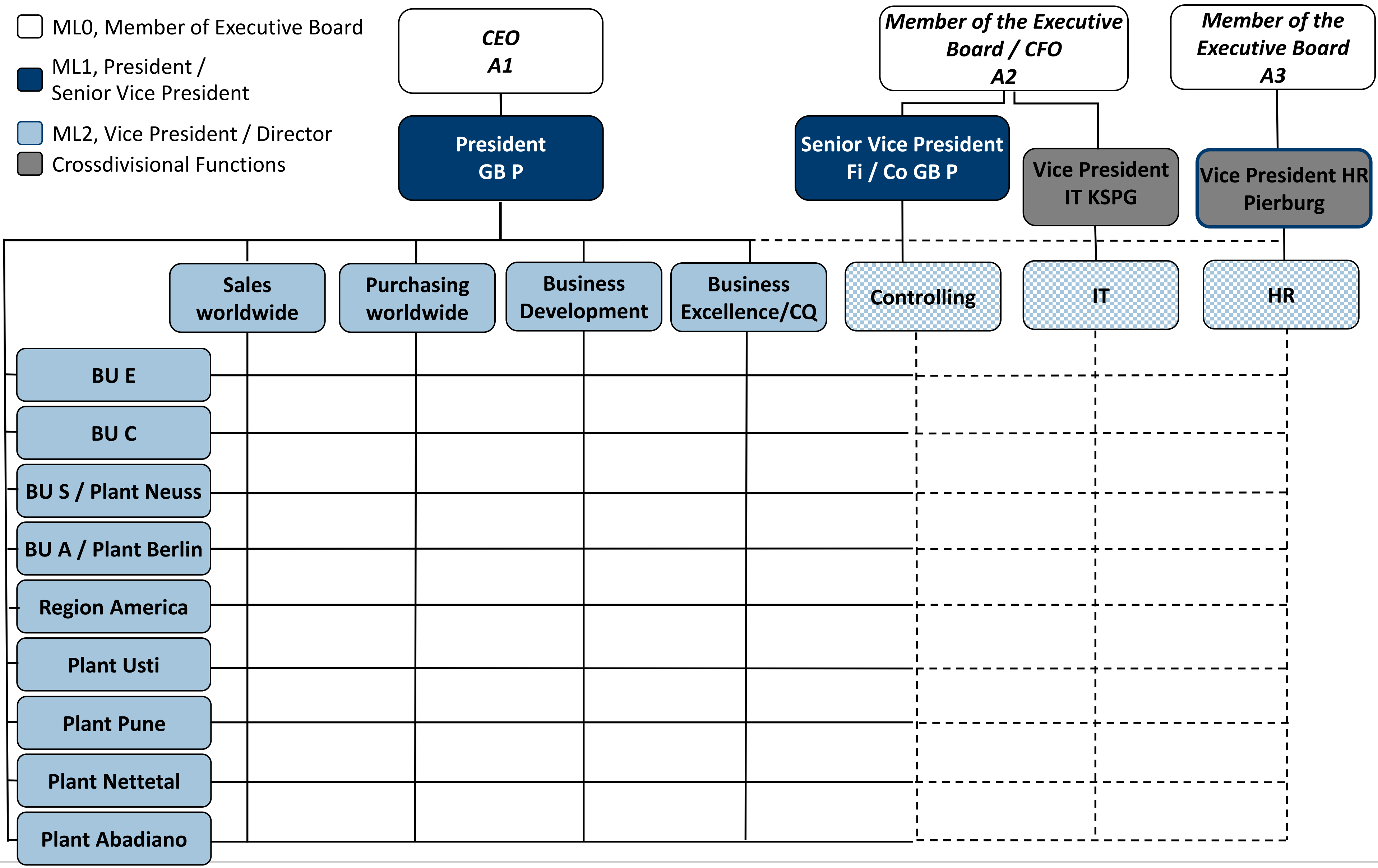
Organisation – Central Engineering




ML0, Member of Executive Board
ML1, President / Senior Vice President
ML2, Vice President / Director
Crossdivisional Functions
CEO A1
Member of the Executive Board / CFO A2
Member of the Executive Board A3
President GB P
Senior Vice President Fi / Co GB P
Vice President IT KSPG
Vice President HR Pierburg
Sales worldwide
Purchasing worldwide
Business Development
Business Excellence/CQ
Controlling
IT
HR
BU E
BU C
BU S / Plant Neuss
BU A / Plant Berlin
Region America
Plant Usti
Plant Pune
Plant Nettetal
Plant Abadiano

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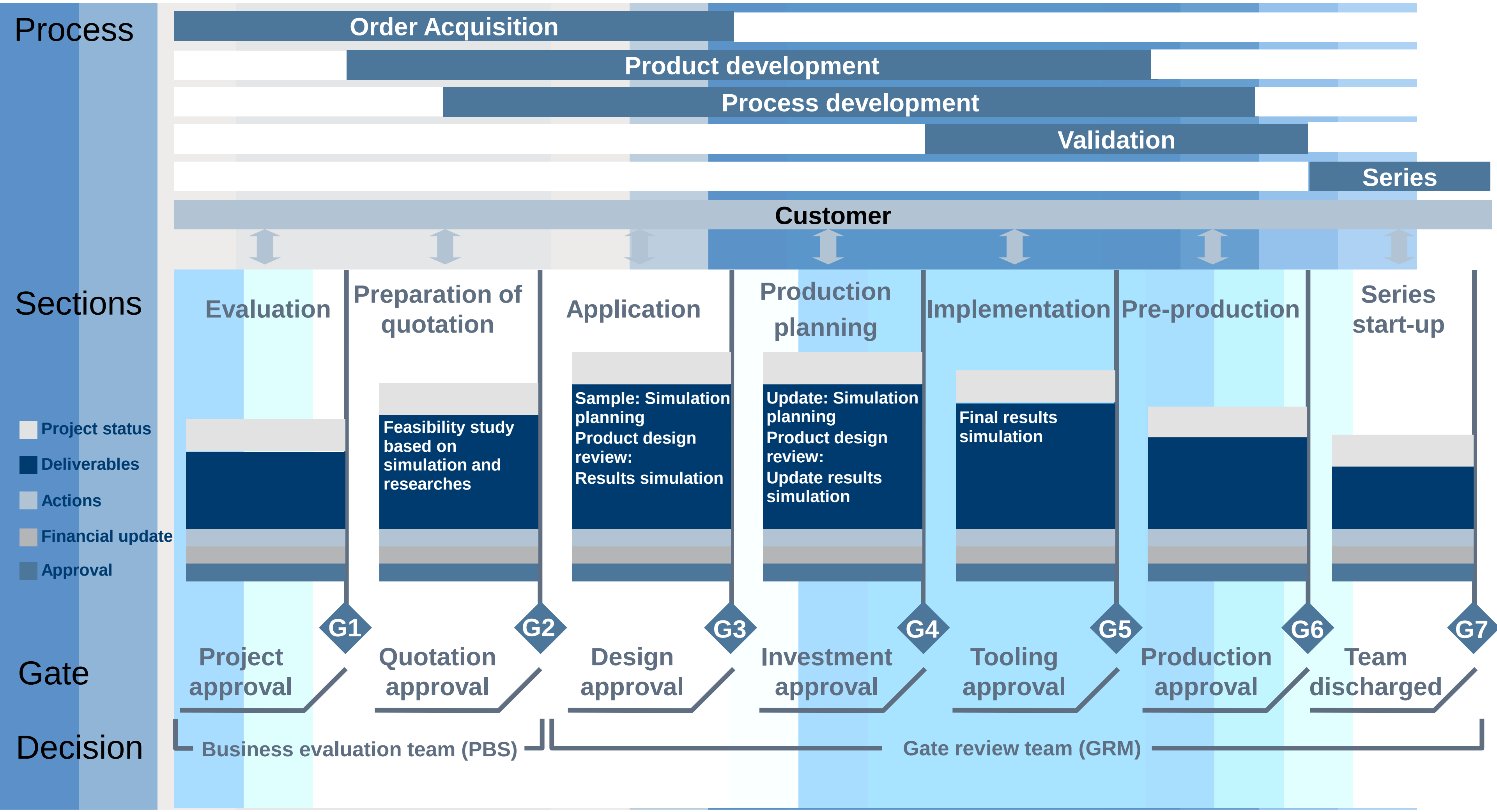
New Pierburg product development process



New Pierburg PDP: Goals

Objectives of the New PDP:

- Reduced development times
- Reduced costs
- Improved product reliability and quality

Major constituents:

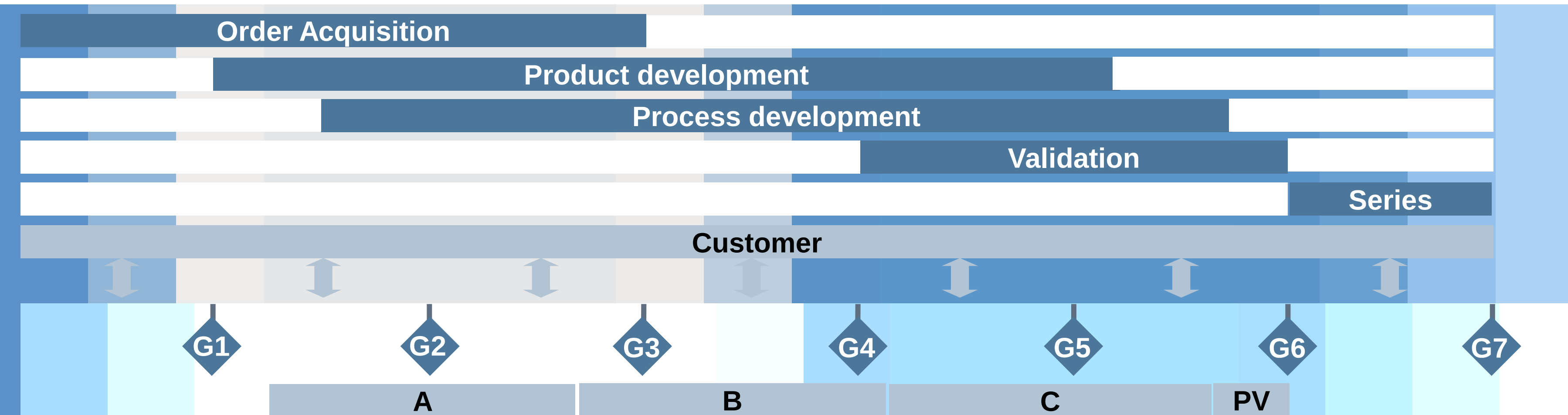
- Controlled project status and defined approval of project phases
- Professional multi-project management and efficient resource management
- Simultaneous engineering
- Frontloading

Important contributions of simulation:

- Realization of frontloading by concepts analysis and feasibility studies
- Virtual prototype testing
- Simulation driven design optimization according to requirements

Strategic analysis results: Implementation of Optimization Tools

Possibilities for application in different project phases:



Topology- and Topography-Optimization

- Optimized component shape in given design space
- Shortening of development times
- Reduction of material usage

Shape- and Size-Optimization

- Minimization of loading by model modification on component surface
- Lifetime enhancement
- Reduction of peak loads

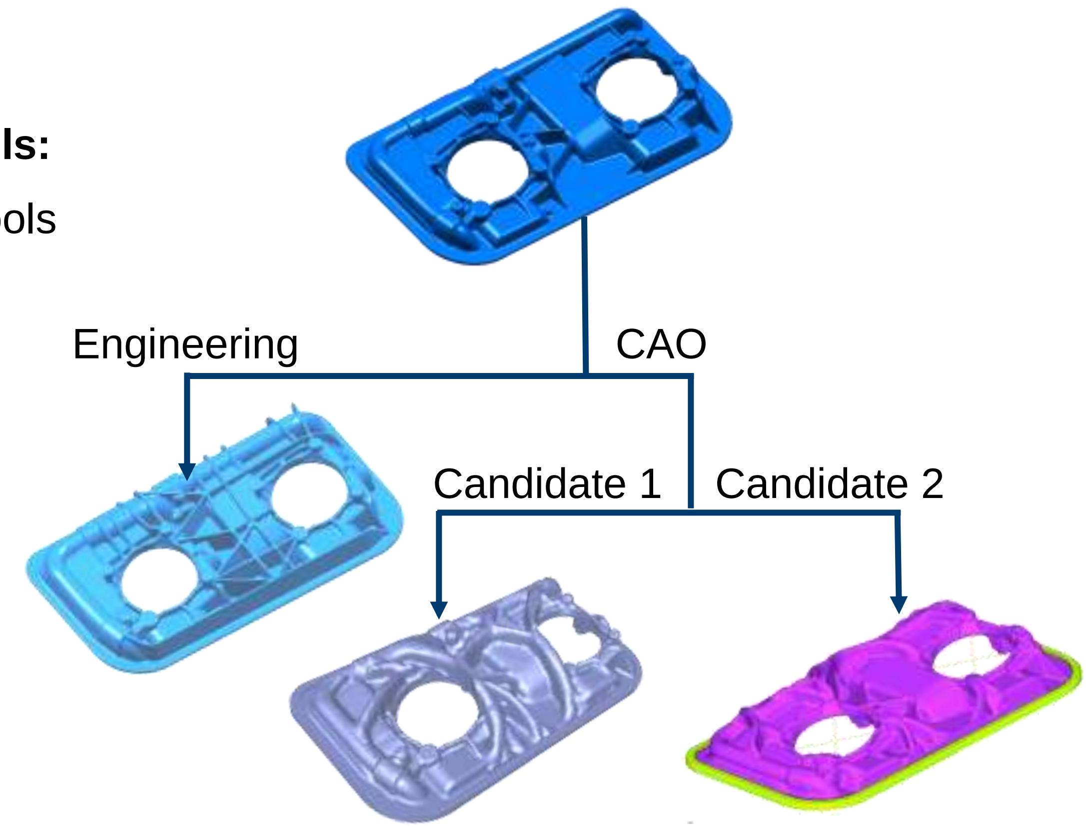
Excellent tools to implement real *Frontloading*

Contents

Implementation approach I

Selection process of optimization tools:

- Benchmark of topology optimization tools
  - One interesting "urgent" example case
  - 1 engineering solution
  - 2 optimization tools results
- Rating of the tools:
  - Input data/model
  - Results quality
  - Supplier performance
  - Usability
  - Costs
- Decision and purchasing
  - First licensing in September 2007
  - First enhancement in July 2008
  - Second enhancement in January 2009
  - Enhancement for next site planned for January 2011



	Original design	Optimized design
Weight in kg	0,556	0,795 (+43 %)
Max. von-Mises stresses in N/mm²	179	39,86 (-78 %)
Max. strains in mm	0,658	0,317 (-52 %)

Implementation approach II

Adoption and rollout of optimization tools:

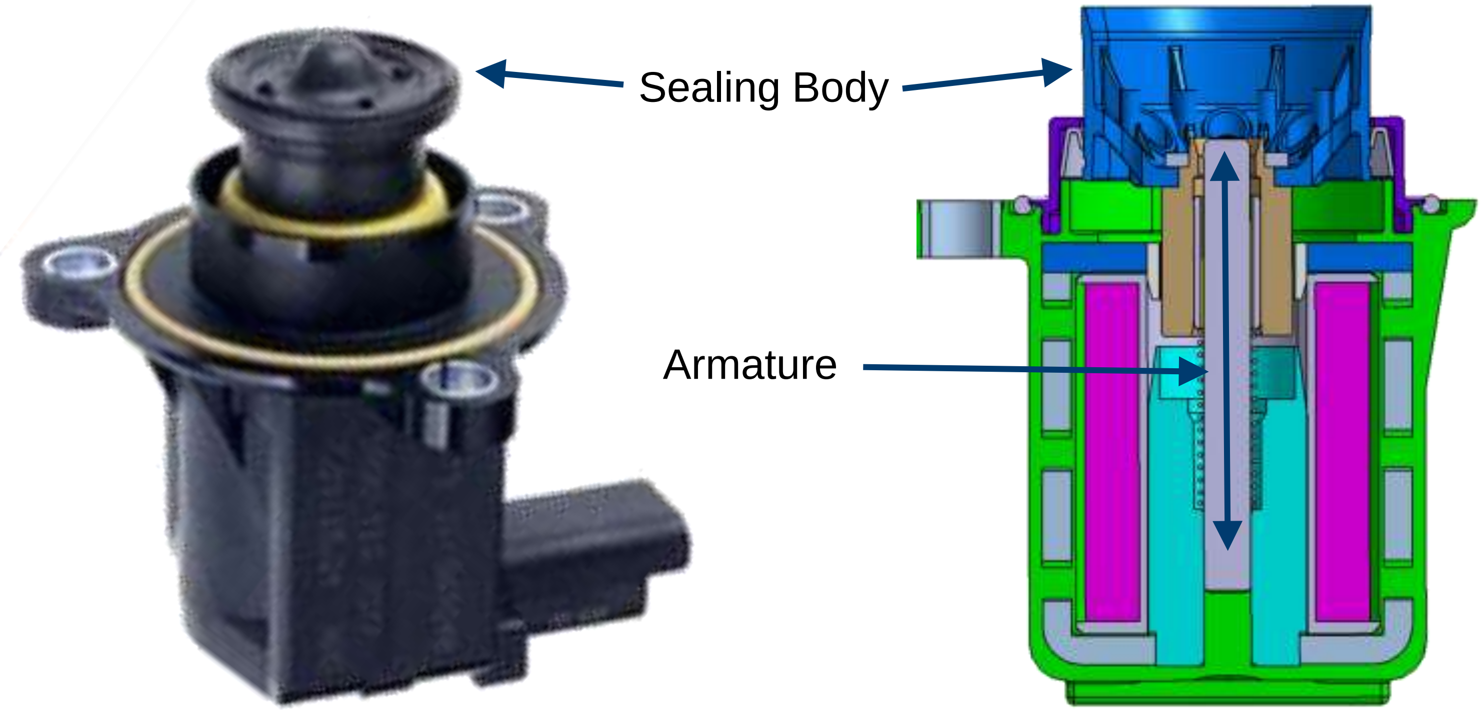
- Training
  - In house, on Pierburg products and examples
  - First 2 CAE-engineers, HyperMesh and OptiStruct in October 2007 for structural mechanics
  - HyperMesh and Morphing in November 2007 for structural mechanics
  - Morphing/HyperStudy for all structural mechanics and CFD engineers in July and August 2008
  - Next 2 CAE-engineers for OptiStruct in April 2009
  - Periodic application-driven support days in 2009 and 2010 and advanced trainings in May and July 2010
  - Simulation team internal projects and simulation internal free training time
- Organizational implementation
  - Integration in development processes and PDP *DRIVE*
  - Promotion and management support
  - Acquisition of internal customers
  - Application to “rescue missions”
- Internal presentations of CAO methods
  - First examples and results with first success and achievements
  - Capabilities and opportunities
  - Vision and strategy

Contents

Example I: Sealing Body I

Sealing body failure of an electrical turbo boost recirculation valve:

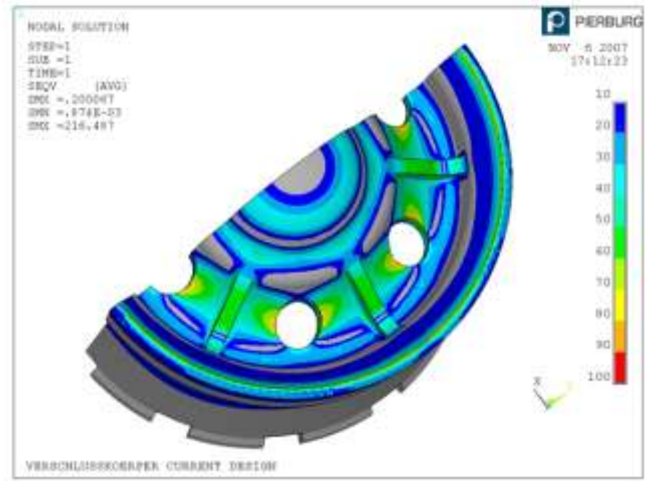
- Used in turbocharger applications in compressor bypass for surge prevention and mapping
- Operational forces due to armature displacements
- Failure of sealing body in early development phase

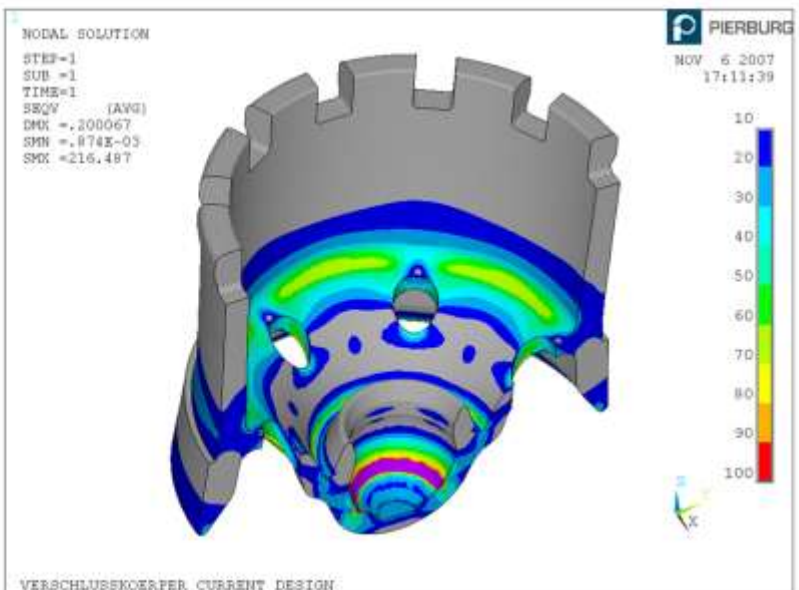


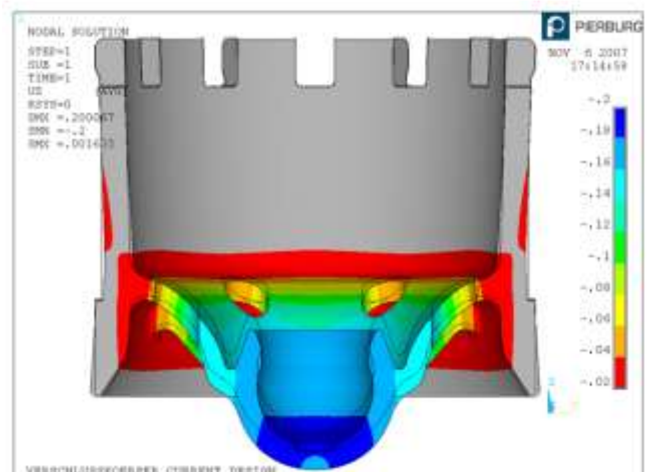
Example I: Sealing Body II

Optimized design by means of iterative ANSYS calculations:

- Changing shape of inner ribs and defining additional ribs
- Result
  - Reduction of maximum stresses to 70-85MPa
  - Increase of stiffness by 3.5% (initial design)





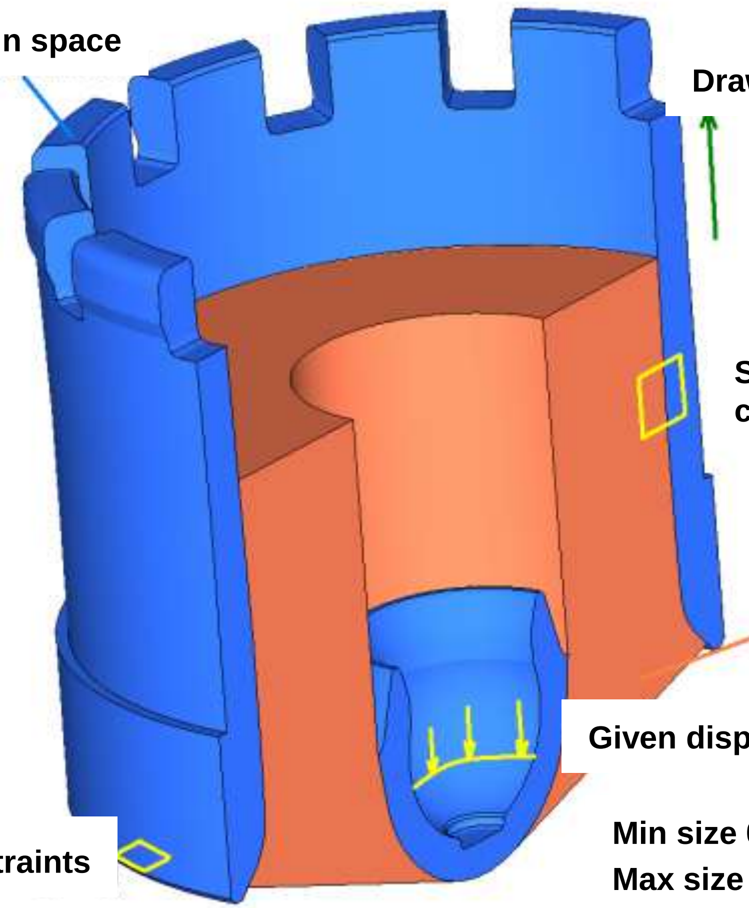


Example I: Sealing Body III

Definition of optimization objectives and constraints

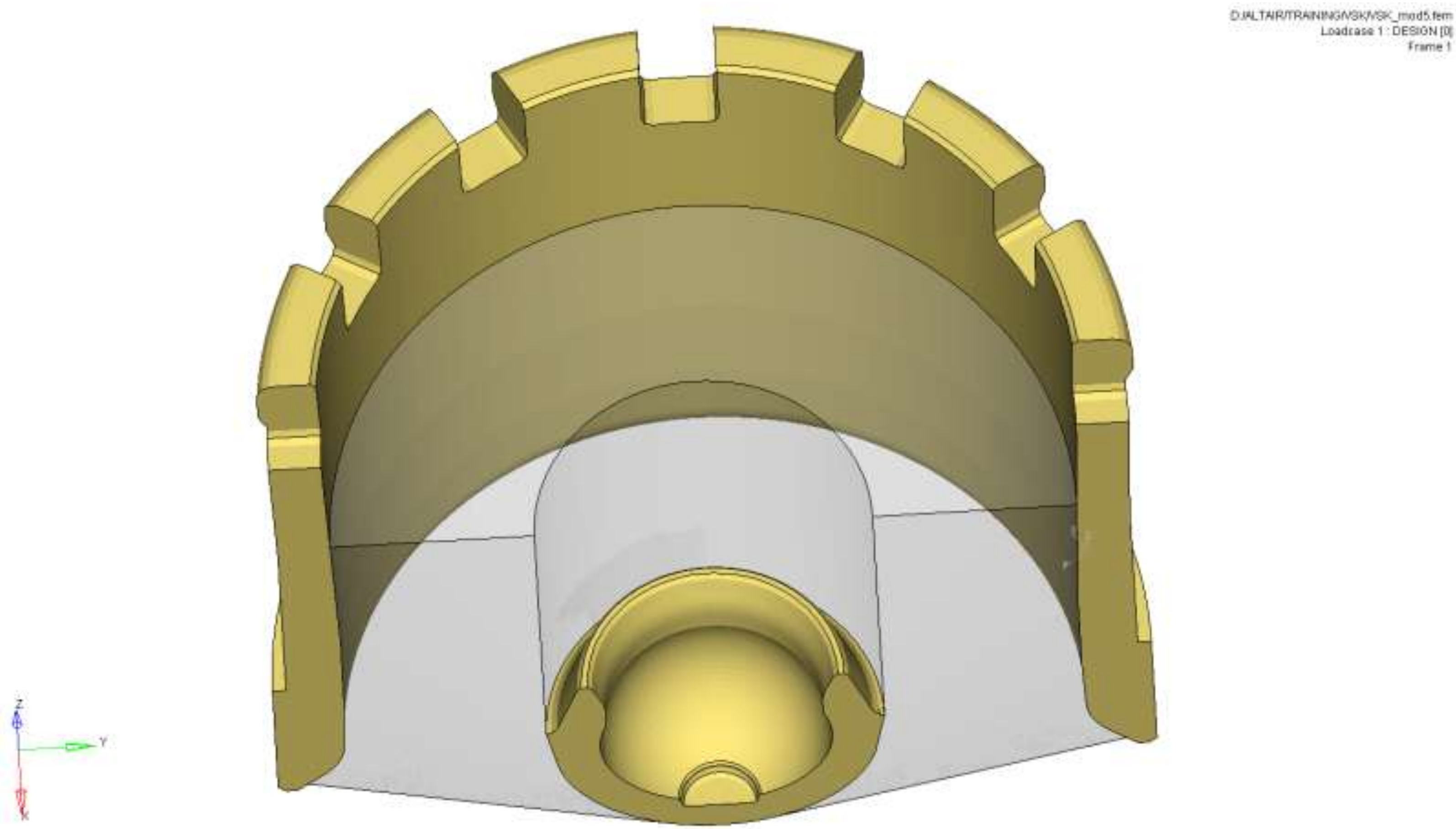
- Maximization of stiffness together with 20% usage of design space

➡ *Effort for adoption of CAD model, Tetra mesh and definition of optimization objectives and constraints approx. 3 h*



Example I: Sealing Body IV

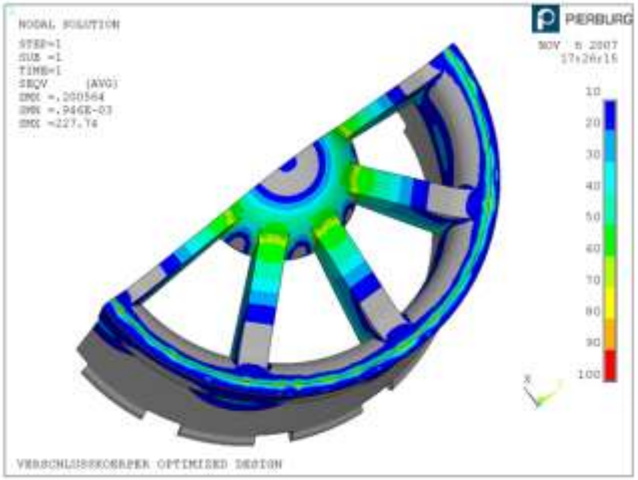
Example: Sealing Body, result after 44 iterations, 24 h CPU-time, 2 processors

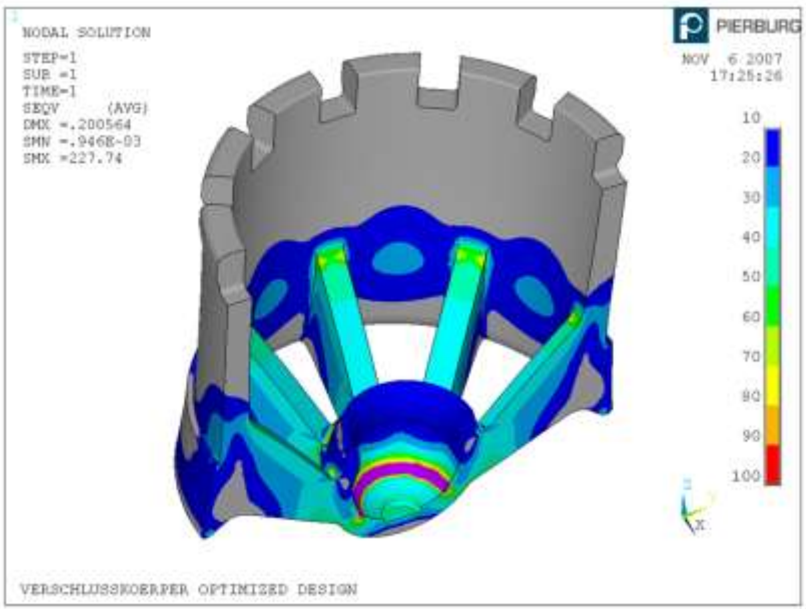


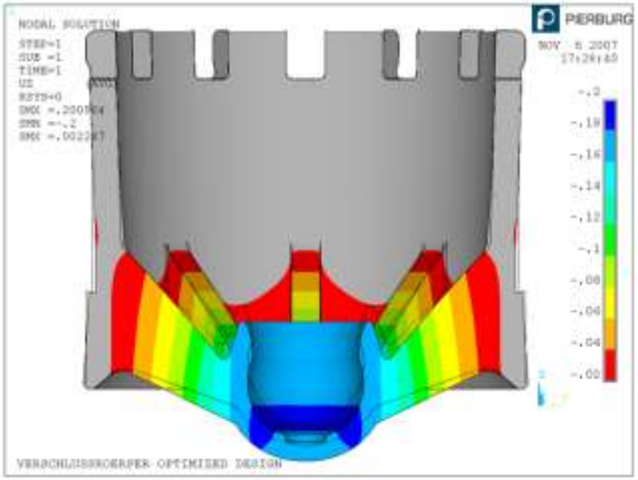
Example I: Sealing Body V

Transfer to new design and recalculation with ANSYS:

- Result
  - Reduction of maximum stresses to 65-80MPa
  - Increase of stiffness by 12%
    (compared to initial design)



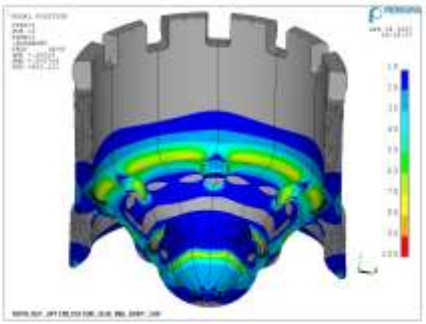


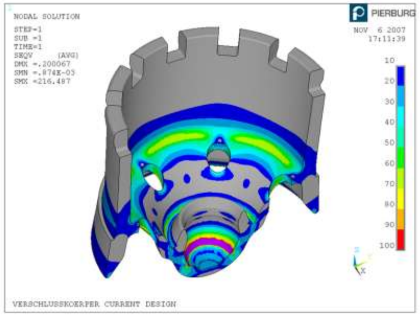


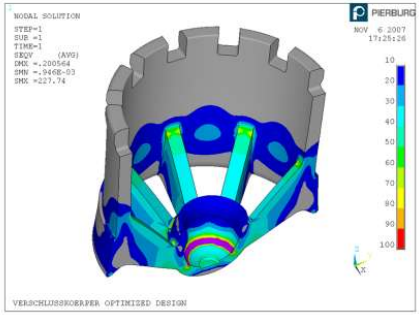
Example I: Sealing Body VI

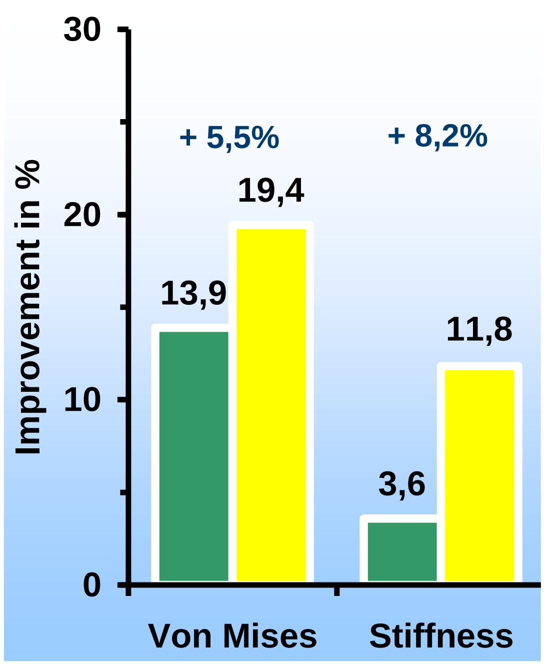
Summary of optimization results

Variant	Von Mises in MPa	Remark	Stiffness in N/mm
Initial Design	75 - 105	No Process- / Manufacturing issues	3180
1st Optimized Design	70 - 85	No Process- / Manufacturing issues	3294
2nd Optimized Design	65 - 80	No Process- / Manufacturing issues	3556







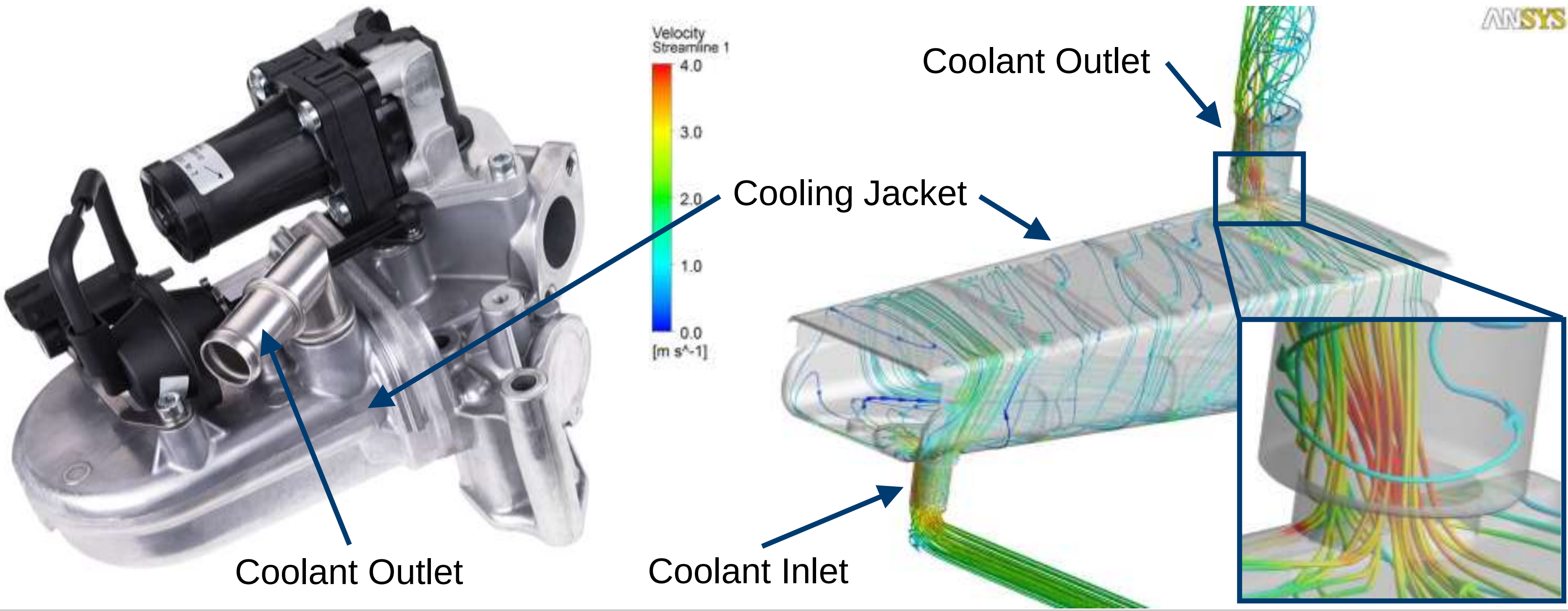


➡ Considerable additional optimization by use of Altair OptiStruct

Example II: Coolant Inlet and Outlet I

Coolant flow optimization in Exhaust Gas Recirculation-System:

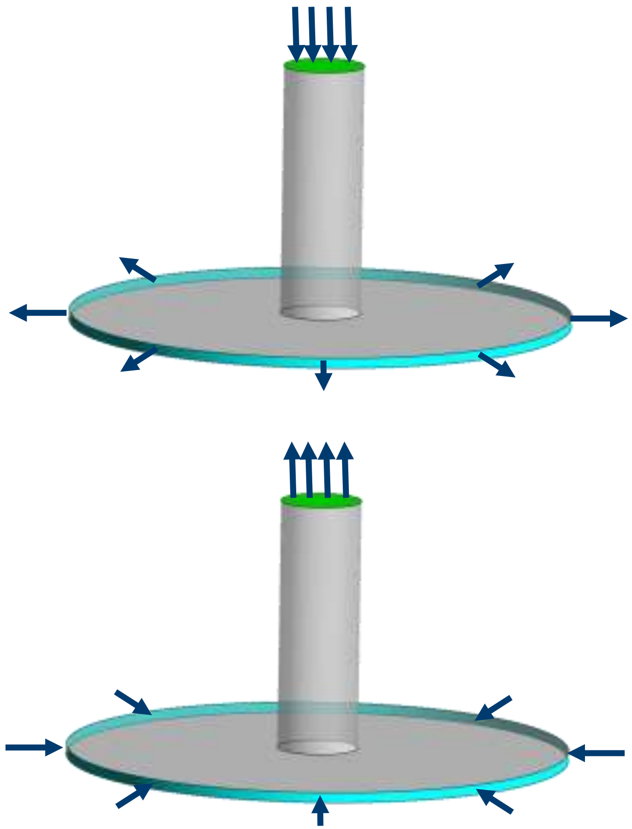
- EGR-Systems are used to reduce emissions (NO_x, HC, Particles, …)
- Hot exhaust gas has to be cooled
- Optimized coolant flow in cooling jacket to ensure efficient cooling and low pressure drop



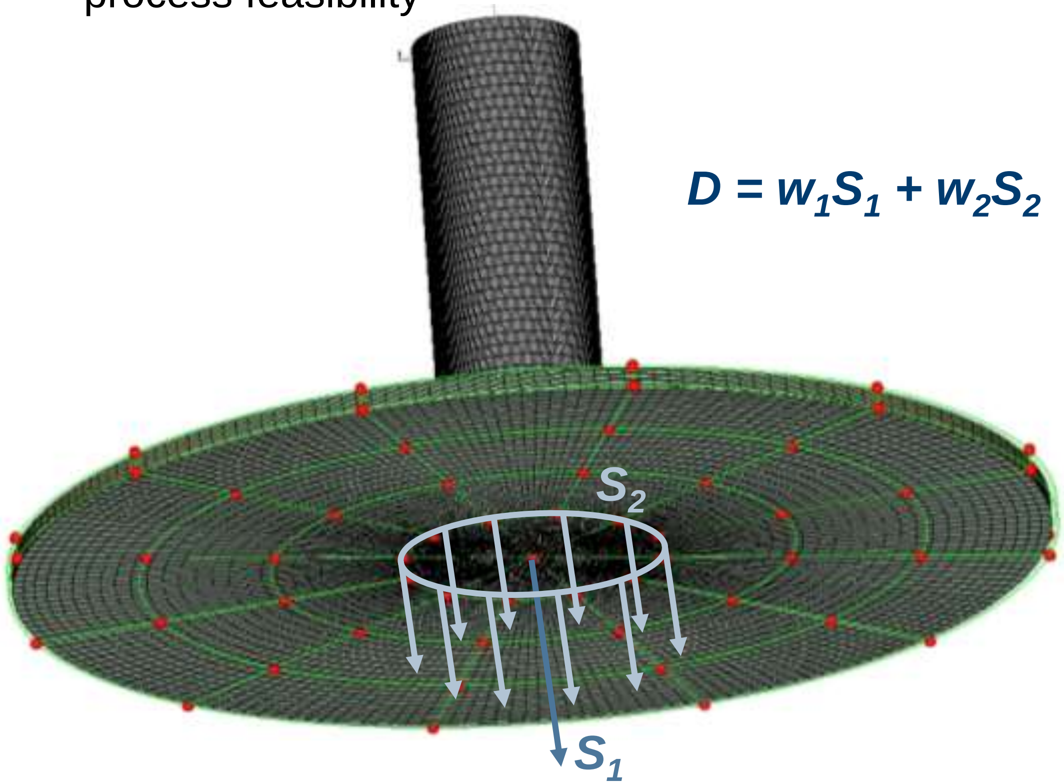
Example II: Coolant Inlet and Outlet II

Optimization of rectangular inlet- and outlet geometries:

- Simplified generic geometry



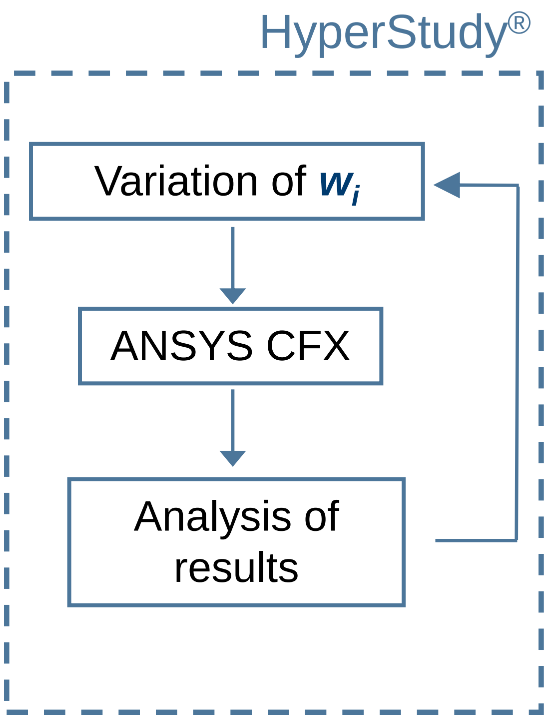
- Definition of Morph-Volume in HyperMesh
- Definition of only 2 *Shapes* to ensure production process feasibility

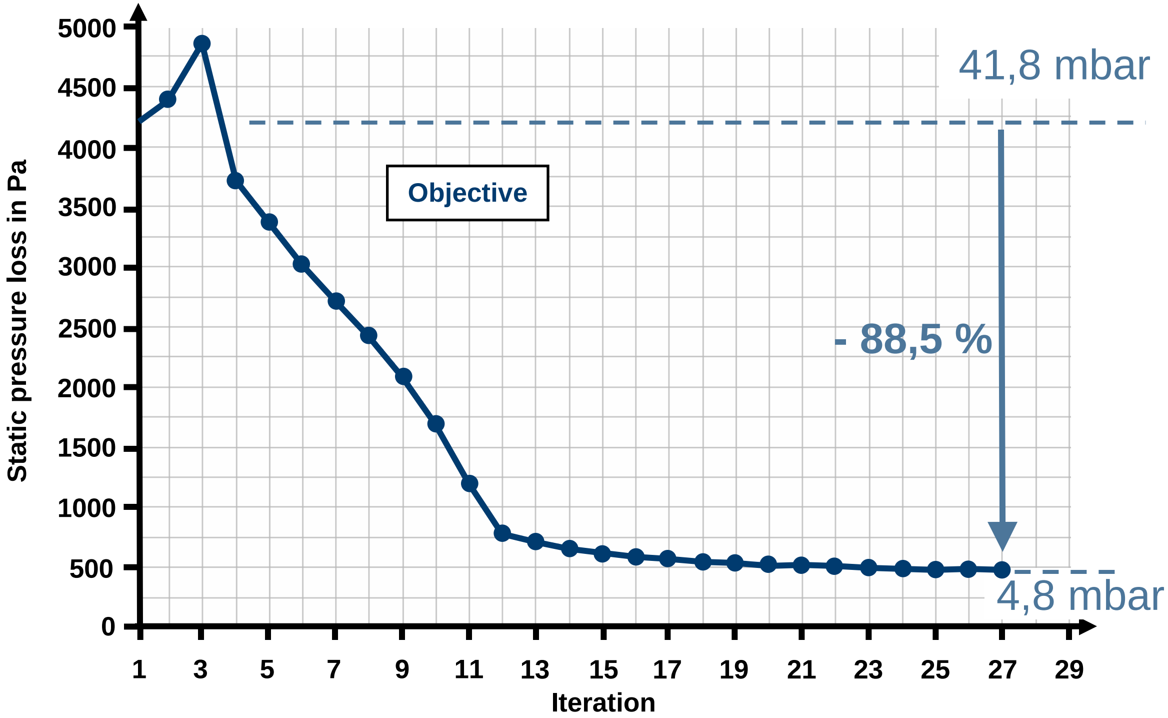


Example II: Coolant Inlet and Outlet III

Optimization with HyperStudy and ANSYS CFX:

- Objective: Minimize static pressure loss
- Run / re-run CFD
- Check results automatically
- Modify geometry automatically



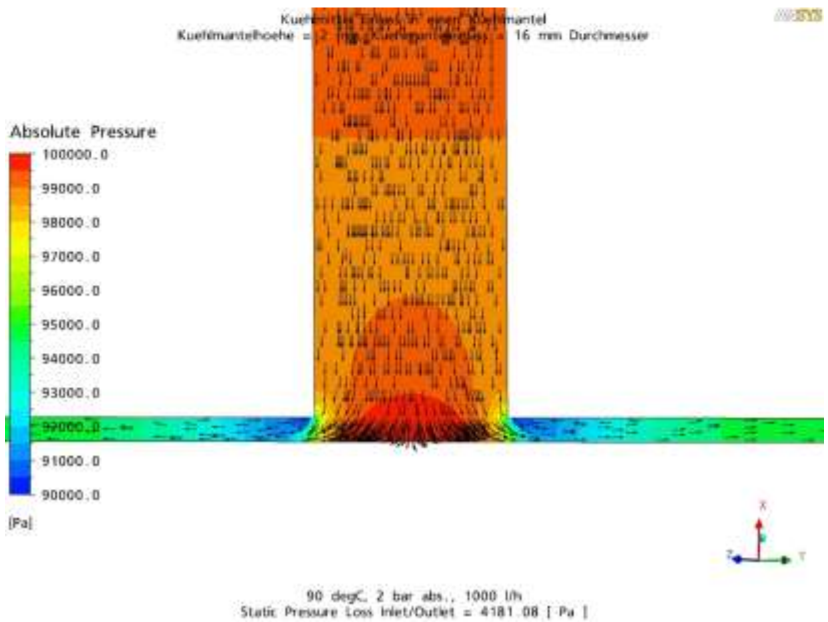


Courtesy of Altair Engineering

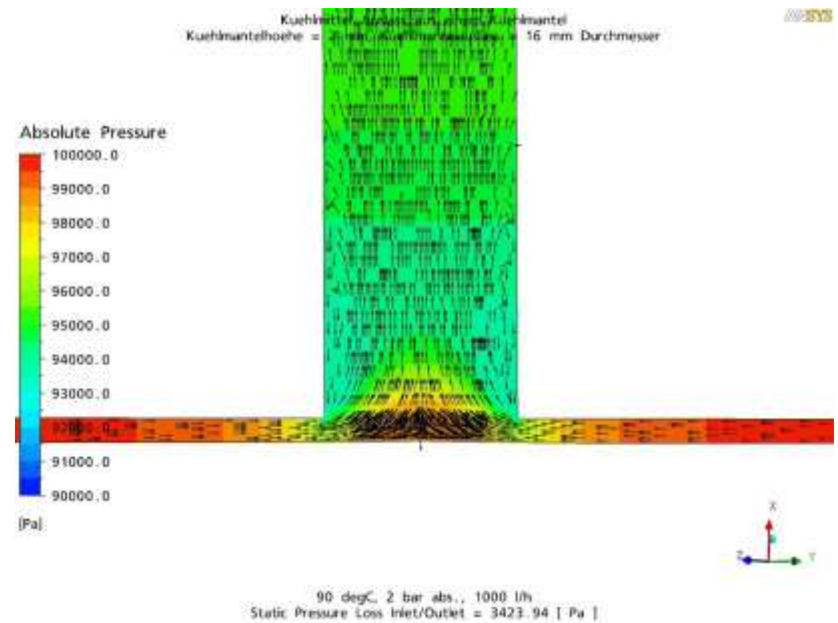
Example II: Coolant Inlet and Outlet IV

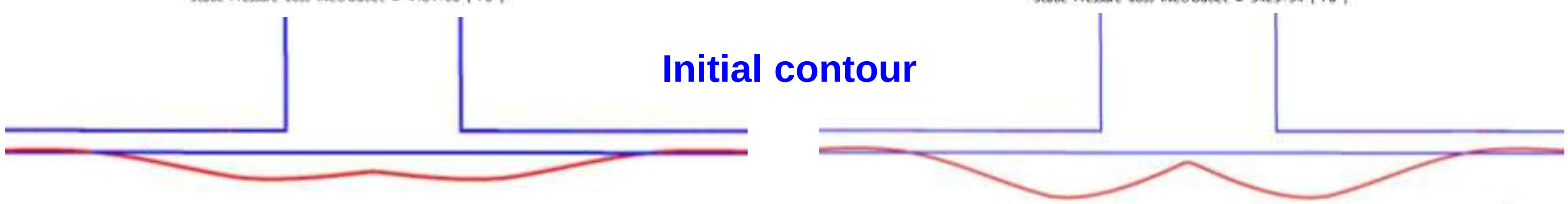
Optimization results:

- Inlet



- Outlet

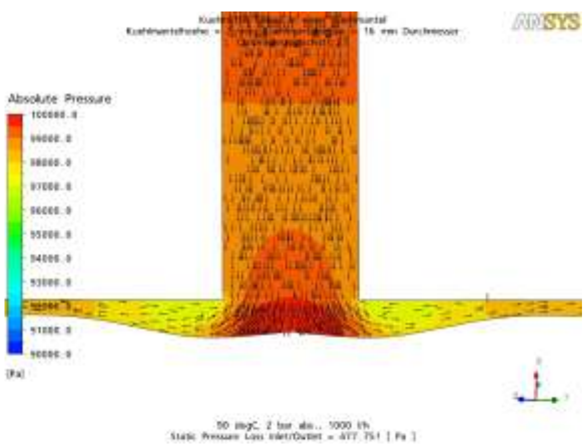


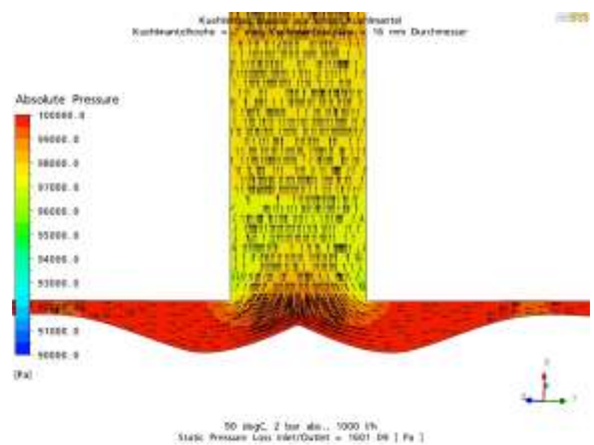


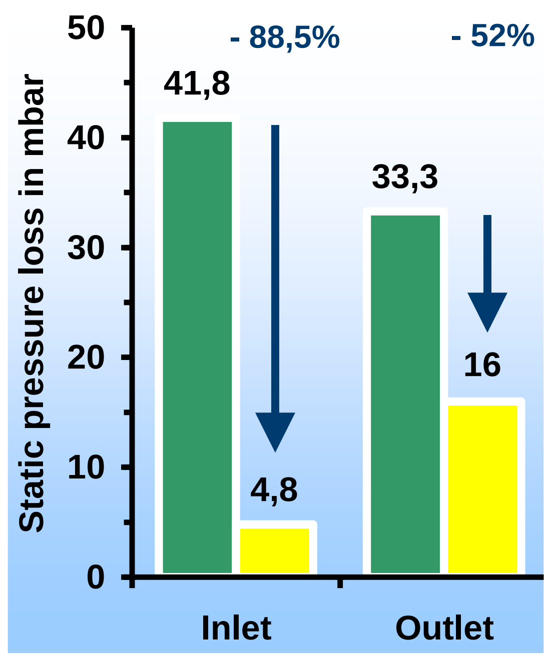
Example II: Coolant Inlet and Outlet V

Summary of optimization results

Inlet Design	Static pressure in mbar	Outlet Design	Static pressure in mbar
Initial Design	41,8	Initial Design	33,3
Optimized Design	4,8	Optimized Design	16





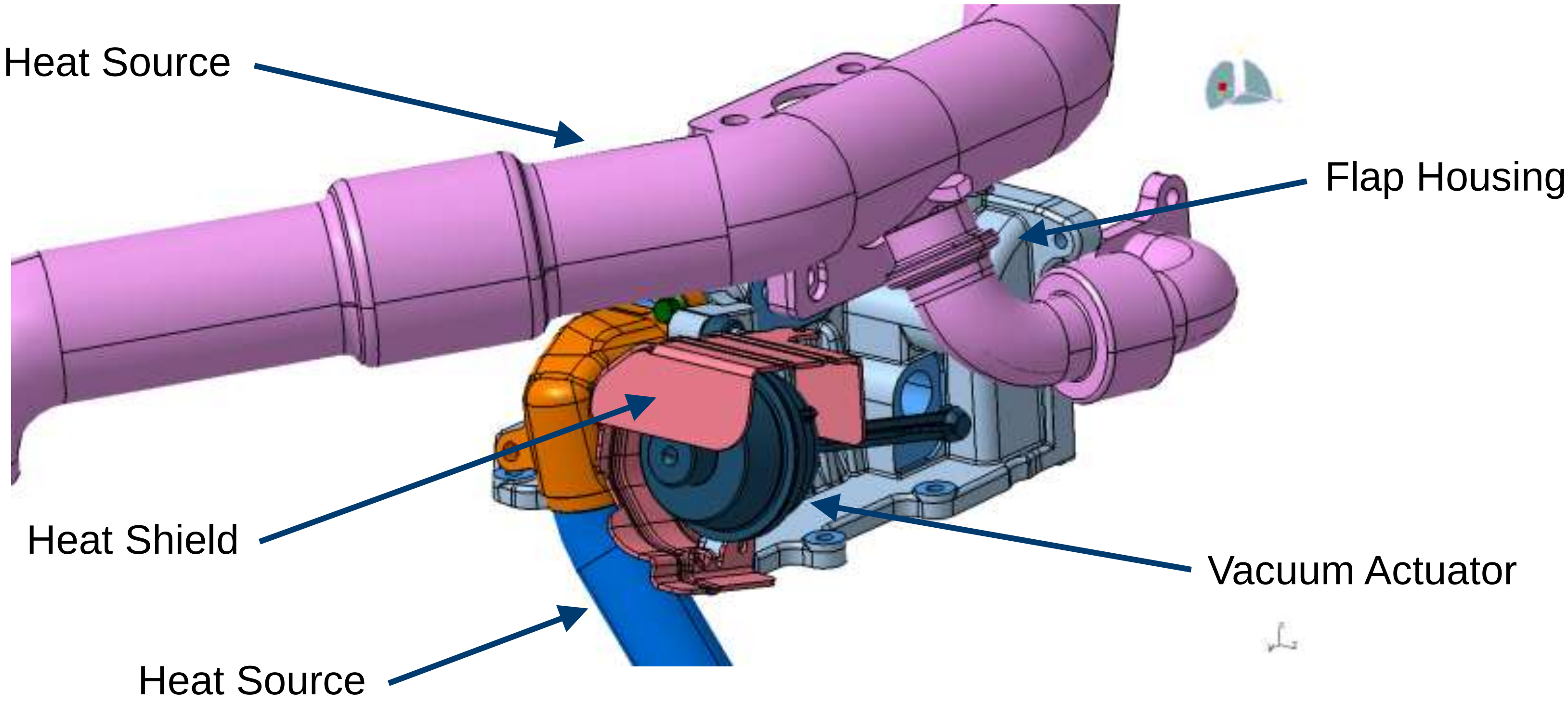


➡ Considerable optimization by use of Altair HyperStudy and ANSYS CFX

Example III: Actuator Heat Shield I

Plastic vacuum actuator needs heat shield:

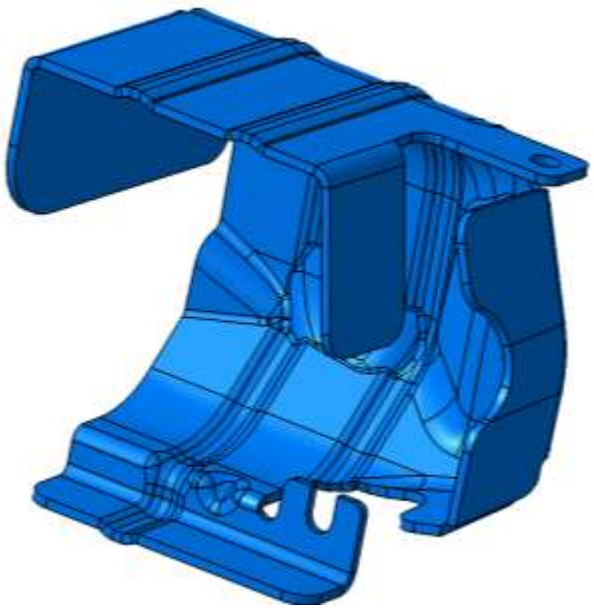
- Cheap design, sheet metal 1 mm thickness
- 1st natural frequency of heat shield should be above 450 Hz



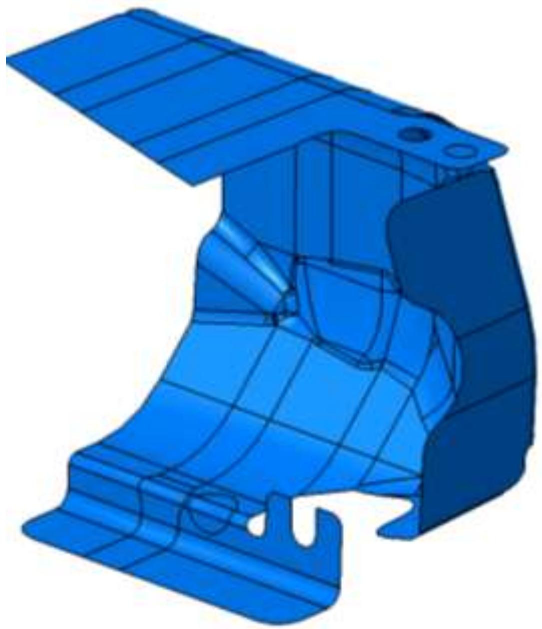
Example III: Actuator Heat Shield II

Initial design and first engineering judgement optimization:

- Removing beads and two wings, additional cut-out and moved top fixing point
- Results
  - 1st natural frequency increased from 155.4 Hz to 350.7 Hz



Initial design: 155.4 Hz

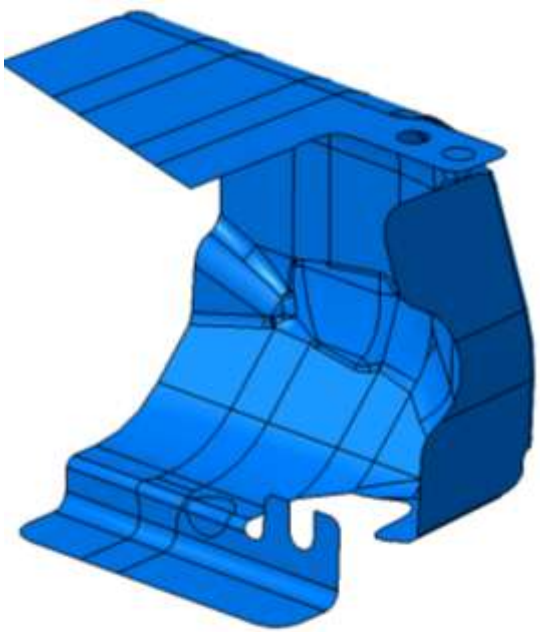


1st optimized design: 350.7 Hz

Example III: Actuator Heat Shield III

Definition of topography (bead) optimization objectives and constraints

- Objective: Maximize 1st natural frequency
- Constraints:
  - Maximum height of beads should not exceed 1.5 – 1.6 mm
  - Draw angle should be between 50 – 70°
  - Areas around fixing points are none design space

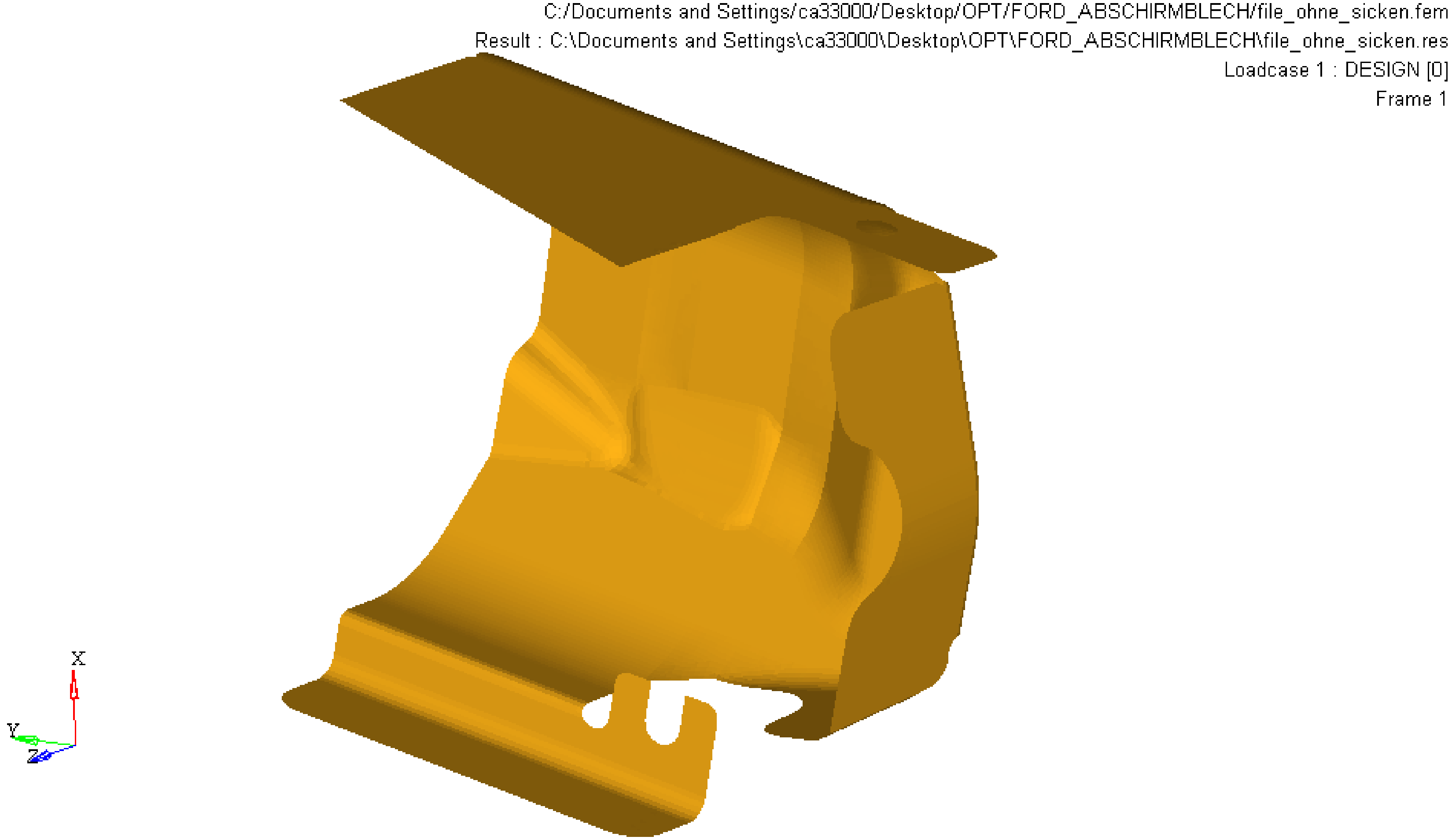


1st optimized design: 350.7 Hz used as new initial design

➡ *Effort for adoption of CAD model, Shell mesh and definition of optimization objectives and constraints approx. 4 h*

Example III: Actuator Heat Shield IV

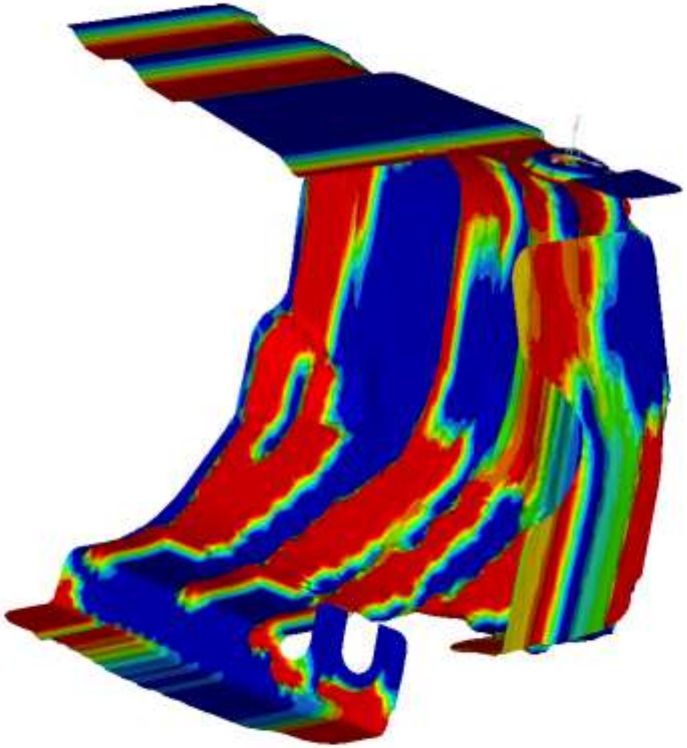
Optimization with OptiStruct, result after 11 iterations, 12 min CPU-time, 1 processor



Example III: Actuator Heat Shield V

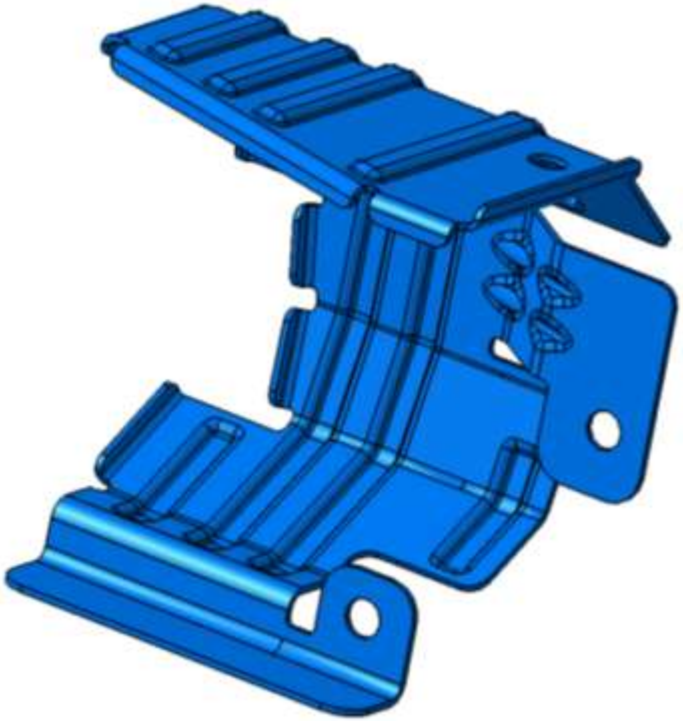
Optimization results:

- Optistruct proposed bead pattern



2nd optimized design: 527 Hz

- Transfer to new design and recalculation with ANSYS

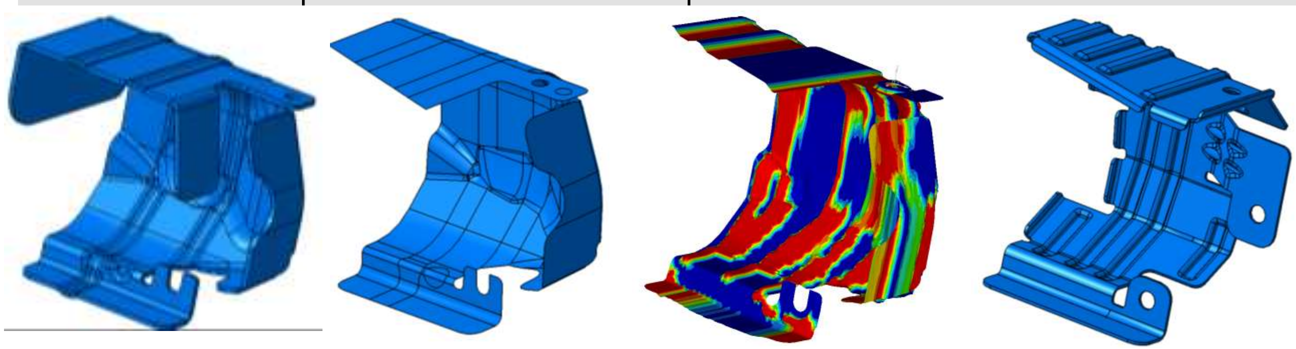


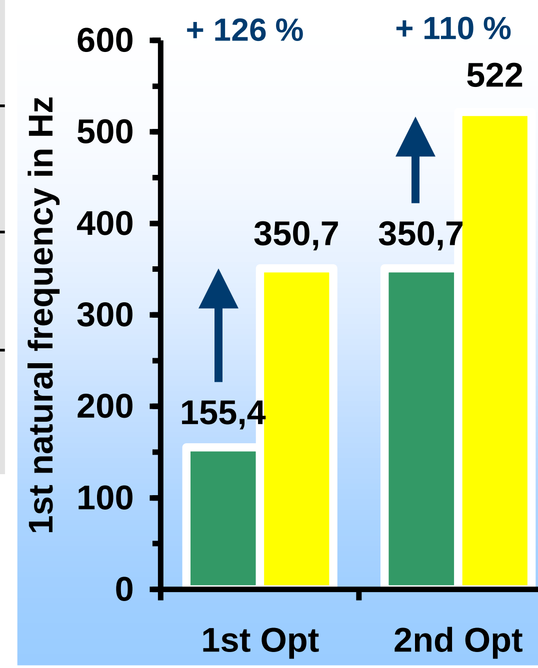
2nd optimized transferred design: 522 Hz

Example III: Actuator Heat Shield VI

Summary of optimization results

Variant	1st natural frequency in Hz	Remark
Initial Design	155.4	Requirements not met (> 450 Hz)
1st Optimized Design	350.7	Requirements not met (> 450 Hz)
2nd Optimized Design	522	Requirements met (> 450 Hz), no Process- / Manufacturing issues



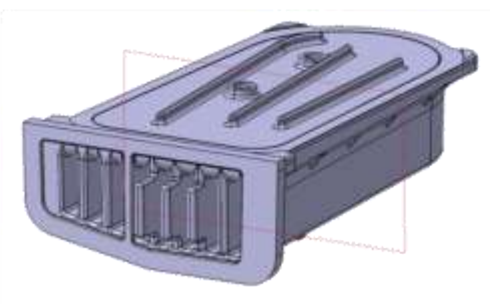


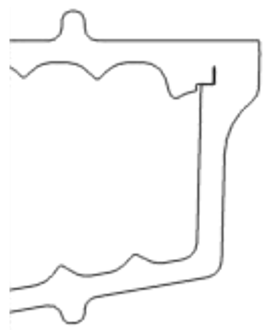
➡ Considerable additional optimization by use of Altair OptiStruct

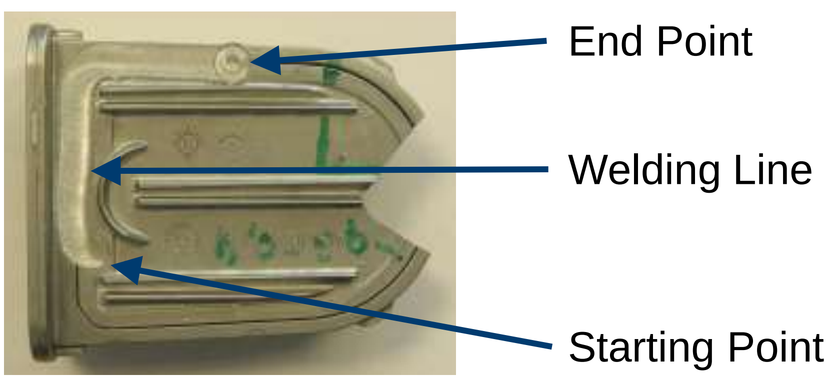
Example IV: Geometric Parameter for FSW design I

Friction Stir Welding of Aluminium EGR-Cooler: Welding zone geometry

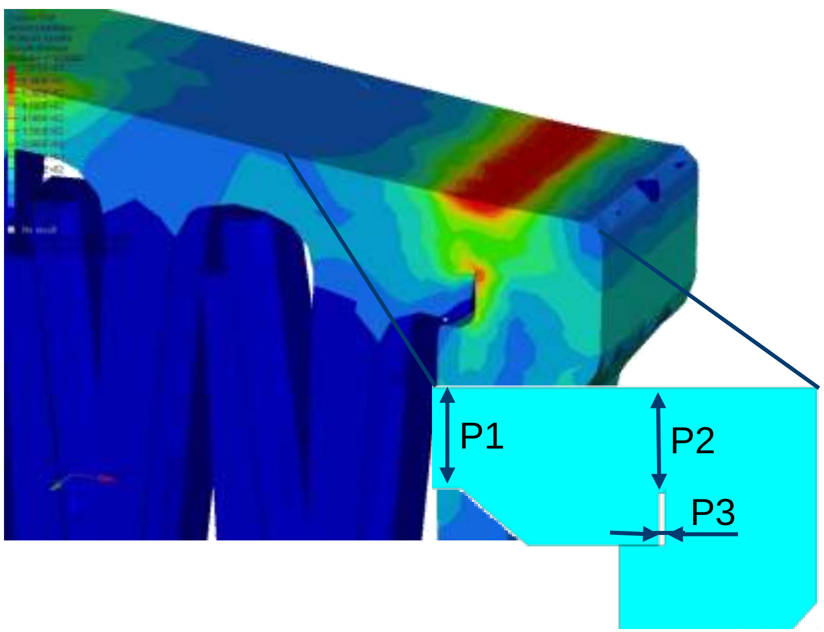
- New welding technology introduced by Pierburg for aluminium pressure die cast parts.
- Analyze impact of simplified basic geometry on strength, stiffness and fatigue.







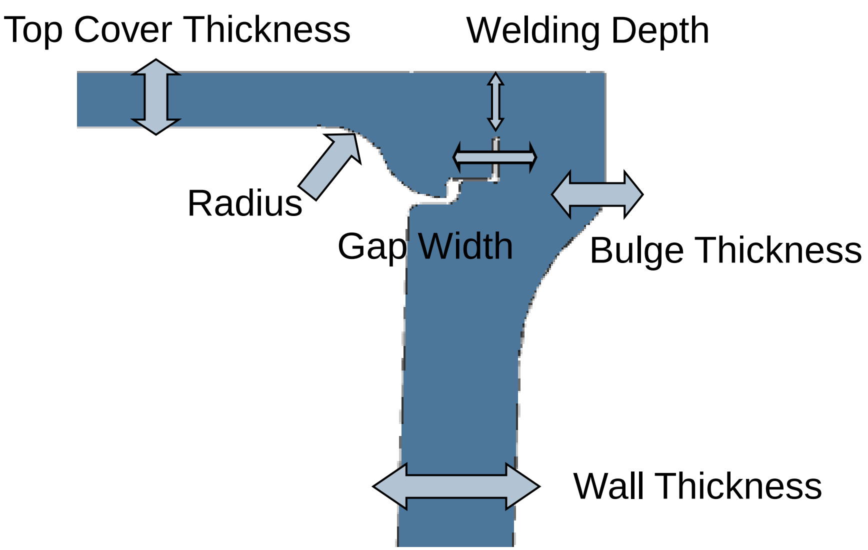
FE-Analysis + Parameterization



Example IV: Geometric Parameter for FSW design II

CAE-supported DoE: Detection and assessment of influencing parameters

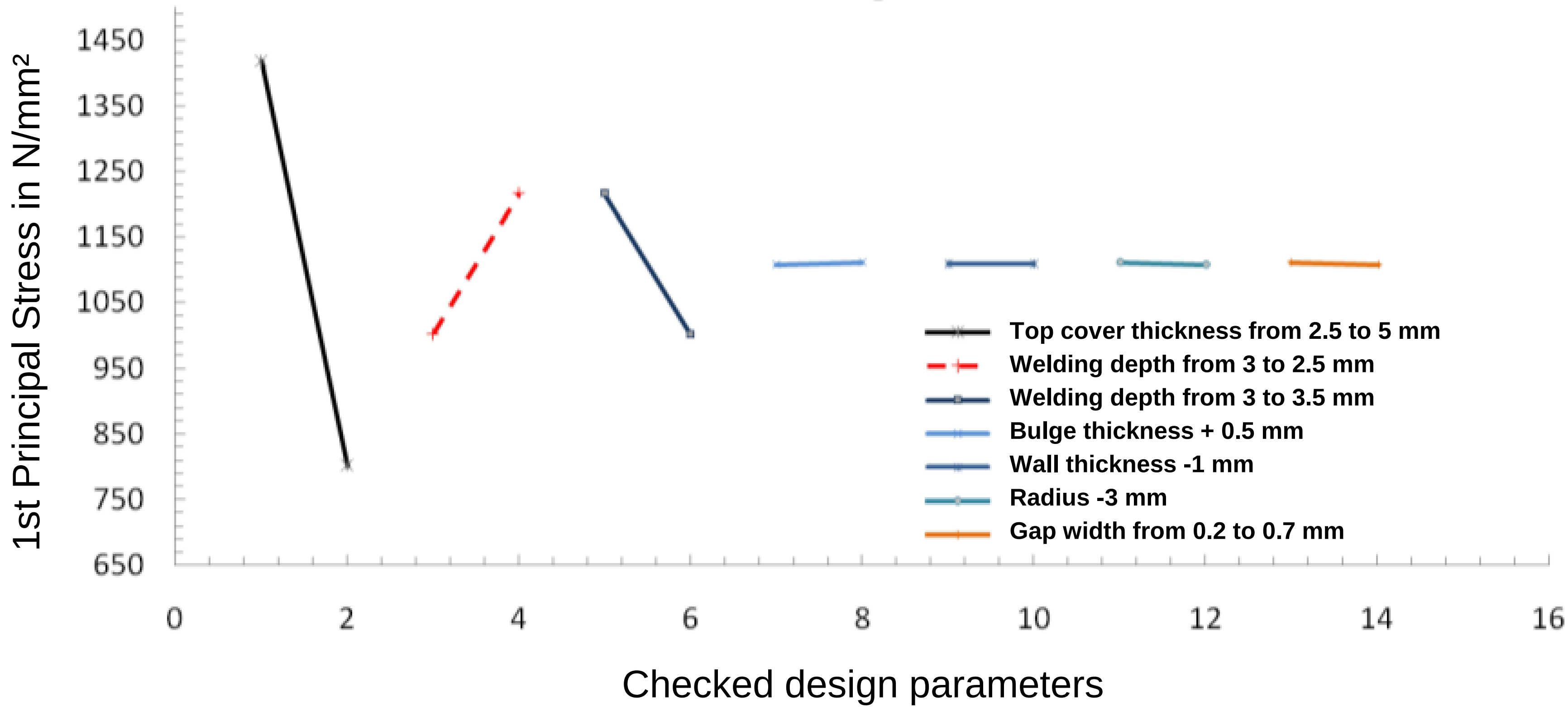
- 7 parameters have been chosen.
- For a full factorial analysis with 7 parameters and 2 steps: $2^7 = 128$ tests would have to be carried out.
- Therefore the first step has been a screening to detect the most influencing parameters.



Example IV: Geometric Parameter for FSW design III

CAE-supported DoE: Screening results

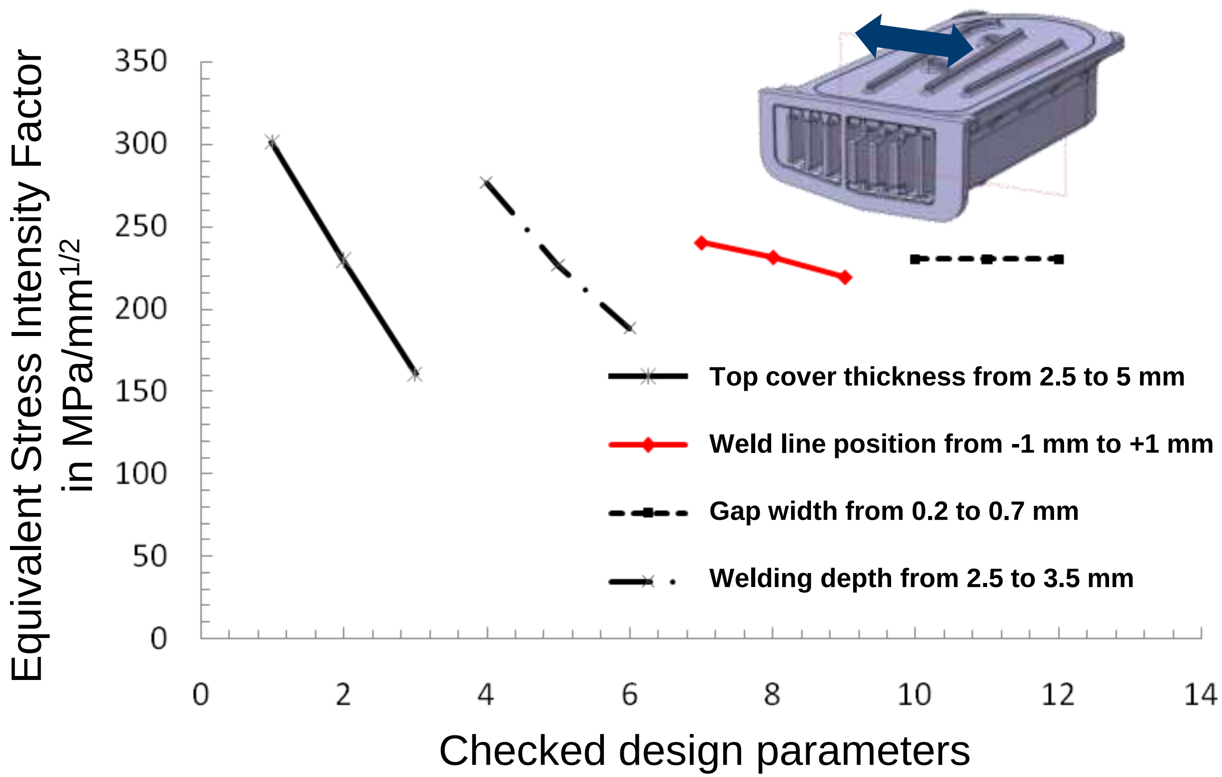
- 7 parameters have been chosen
- 3 parameters have high impact on 1st principal stress



Example IV: Geometric Parameter for FSW design IV

CAE-supported DoE: DoE on main effects including weld line position

- 4 parameters have finally been chosen (with additional parameter weld line position)
- Objective: Minimize equivalent Stress Intensity Factor within parameter range



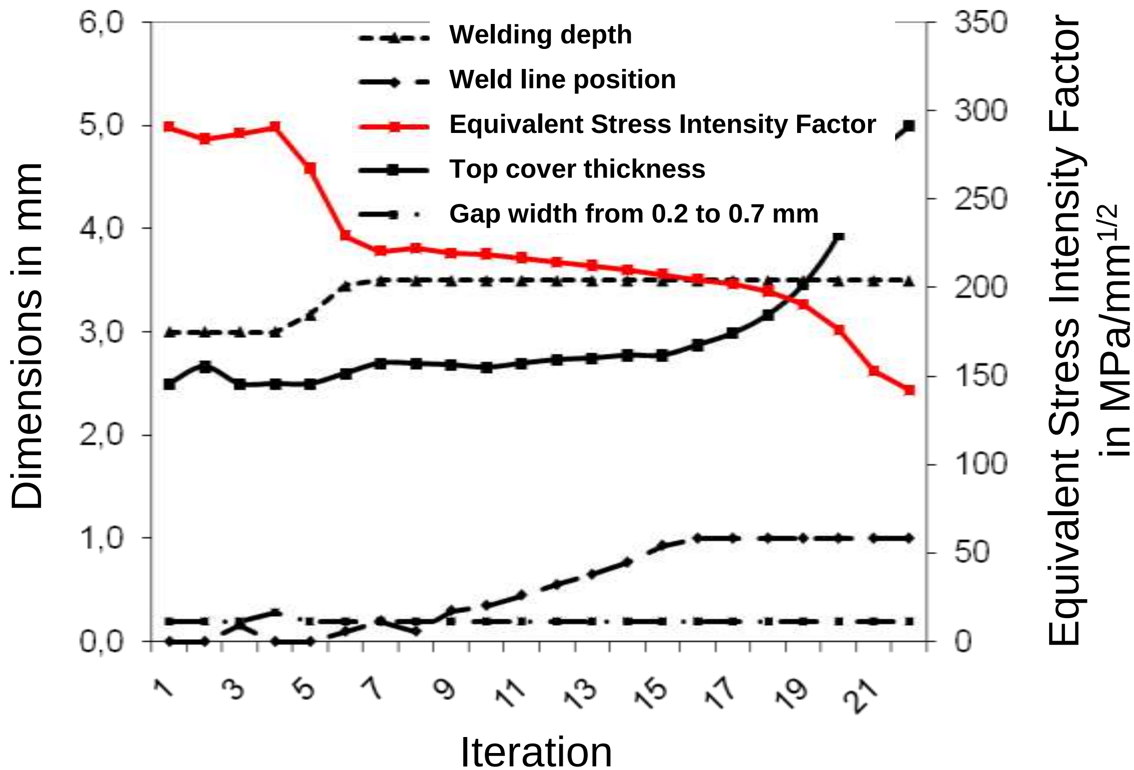
Results:

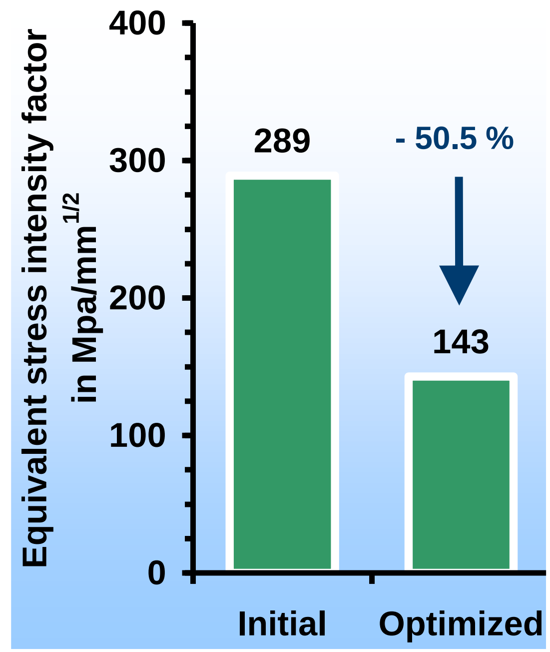
- 3 parameters have high impact on equivalent stress intensity factor
- Lower top cover width has positive effect on life time of the welding line
- Because the lower width leads to lower displacements of the top cover

Example IV: Geometric Parameter for FSW design V

Geometry optimization with HyperStudy and ANSYS:

- Optimization with Adaptive Response Surface Method





- Optimization leads to maximum top cover thickness and maximum welding depth
- Equivalent stress intensity factor could be reduced by 50 %

➡ Efficient parameter optimization by use of Altair HyperStudy

Implementation Experiences

Lessons learned:

- Training
  - Successful in house training, good advantage to learn on Pierburg products and examples.
  - More training days, especially if HyperMesh training is needed, too.
  - To start not with the whole group leads to potential concentration of operational tasks, but
  - Risk of two or more groups of users with different level of experiences and knowledge.
  - Periodic application-driven support days are very successful.
  - To get additional simulation internal projects and simulation internal free training time has been very difficult, especially during current financial crisis impacts.
- Organizational implementation
  - The formal integration in development processes and PDP *DRIVE* has been easy, the real usage of the tool remains difficult, therefore additional promotion and management support is needed.
  - Acquisition of internal customers is still difficult, except there is a need to rescue a project design.
- Internal presentations of CAO methods
  - Big need for internal presentation of first examples and results with first success and achievements.
  - Design and Project Management need to know the capabilities and opportunities of CAO.

Contents

- Introduction
- Structure of simulation within R&D organization
- New product development process *DRIVE* and contribution of optimization tools
- Implementation approach
- First experiences
- Summary

Summary

The introduction of numerical optimization tools into the Pierburg *DRIVE* product development process has been successful:

- The tools are one of the most important drivers to realize "Frontloading" and to remain competitive on the market.
- Throughout the whole product range they could provide innovative and better solutions.
- Well trained experts and strong support of the management are needed until the tools are firmly established within the organization.
- The different methodologies, topology, topography, size optimization and DoE provided very promising results.

To gain full integration of the tools and to achieve full internal customer satisfaction:

- The vision and strategy for CAO tools has to be presented internally again and again.
- Convincing examples and impressive solutions are still needed.
- Still effort for CFD optimization has to be spent to obtain the full range of results here, too.

Thank you for your attention

KSPG AutoMotivePower

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