Fluid Optimization Workflows for Highly Effective Automotive Development Processes (FLOWHEAD)

WORKFLOW EXAMPLE FOR NON-PARAMETRIC SENSITIVITY BASED ITERATIVE TOPO AND SHAPE OPTIMIZATION LOOPS

Thomas Schützle, Michael Böhm, Jürgen Sauter
FE-DESIGN GmbH, Munich, March 26th, 2012

Overview

- Introduction / Review
- WP2 / Demonstrator Framework
- Topological optimization loop
- Shape optimization loop
- Summary and Future developments

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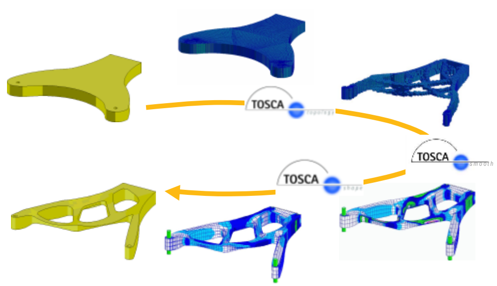
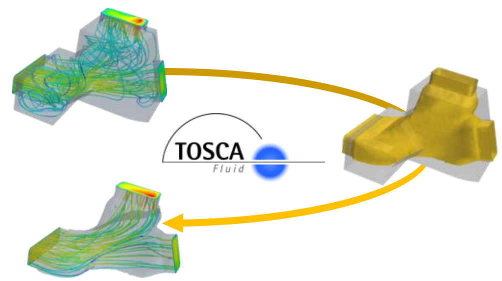
TOSCA Structure

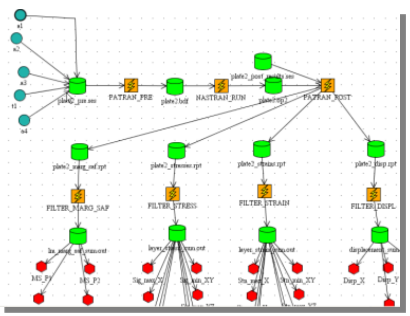


TOSCA Fluid

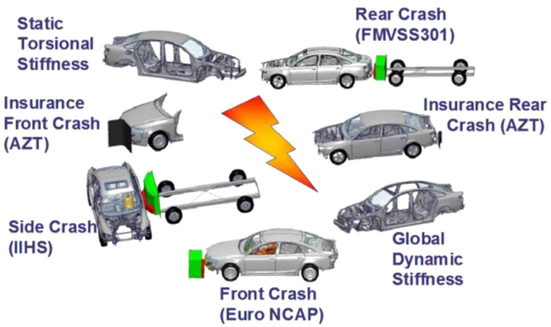


Customization

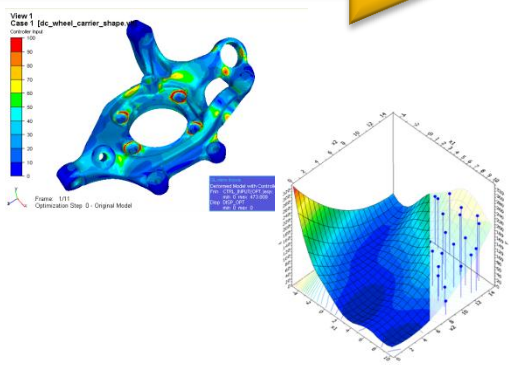
Software Development and Engineering Services



Process Automation



Multidisciplinary Optimization



Visualization/Evaluation

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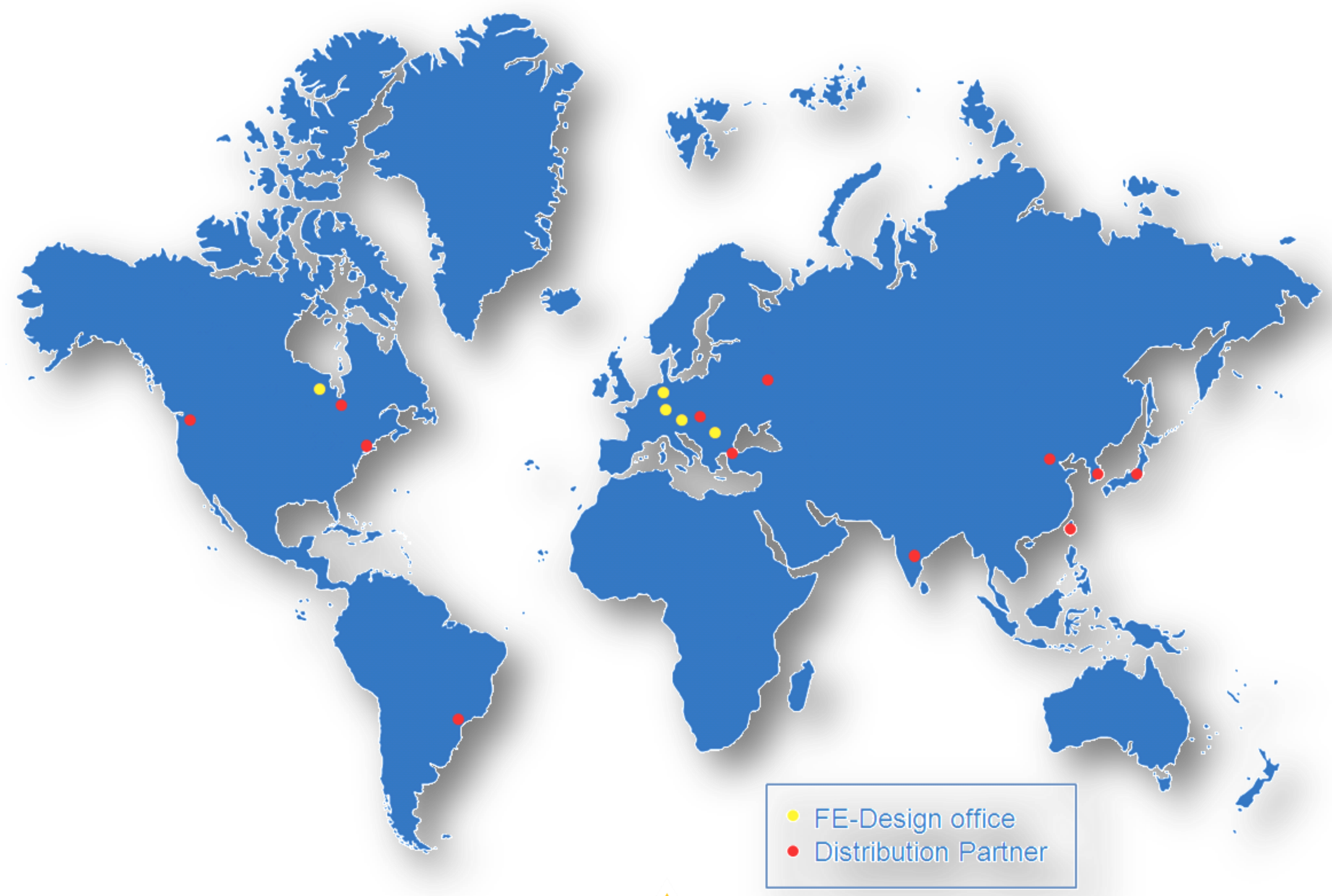
FE-DESIGN: Locations and Partners



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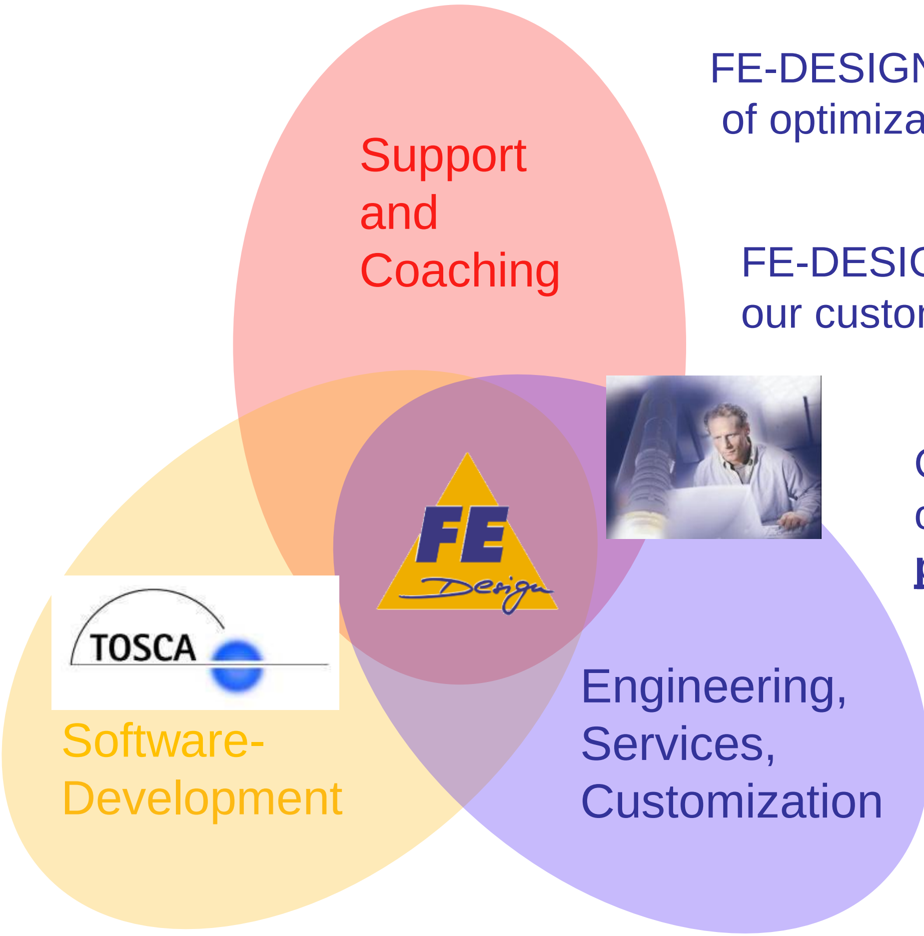
Your Partner for Optimization



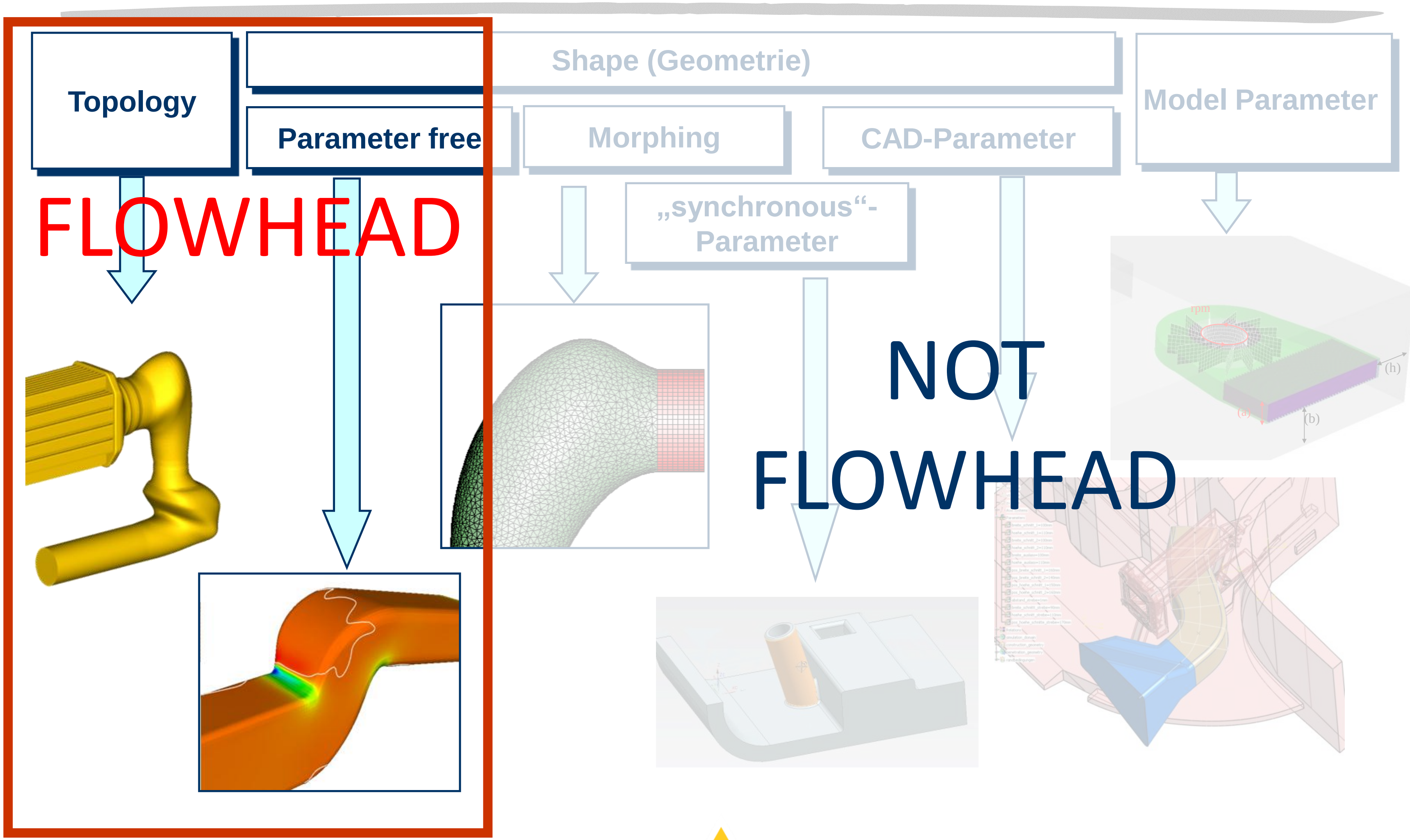
FE-DESIGN **combines development and engineering** of optimization-methods

FE-DESIGN has the ability to deliver best solutions for our customers, **benefiting from multi years of experience**

Our customers improve their optimization processes continuously due to a **permanent know-how-transfer with FE-DESIGN**

Customers leverage FE-DESIGN´s knowledge, **embedded in long-term business relationships**

Parameterization technologies for geometry – CFD Examples



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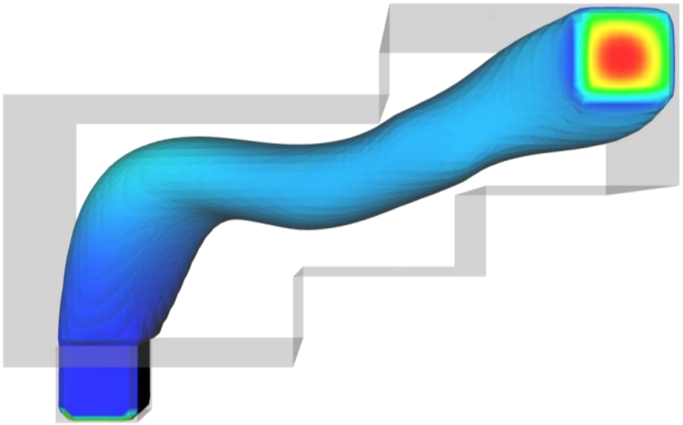
Retrospect - What will be the result of FlowHead ?



- Sensitivity based design optimization
- Multi criteria optimization
- Optimization with respect to manufacturing constraints

Challenges to get optimization “used” in the **industrial development process**

- Optimization processes have to fit into the PDP
- The designer / engineer has to be guided through the optimization
- The approach should be easy to use and stable

Retrospect – “Software view”

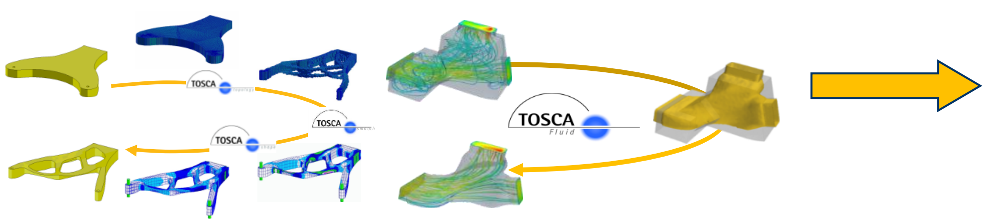
Even more challenges and things to think of …

- Sensitivity filtering
  - Different algorithms for shape and topology optimization
- Optimization algorithm
  - In FLOWHEAD we use MMA but an interface to integrate other algorithms should be present
- Result extraction and smoothing
  - Creating closed surfaces from topological optimization results
- Mesh treatment during shape optimization
- ...

Retrospect – “The users view”

- An optimization tool has to be user-friendly
- An application in a large production cluster environment has to be stable – especially regarding clean up
- Real problems are in general very big and we need parallel applications to deal with them
- There are different optimization methods and we do not want to use a specialized tool for each of them
- There are a several software products in the PDP and we need to think about interfaces and easy ways for data transfer

TOSCA Structure **TOSCA Fluid**

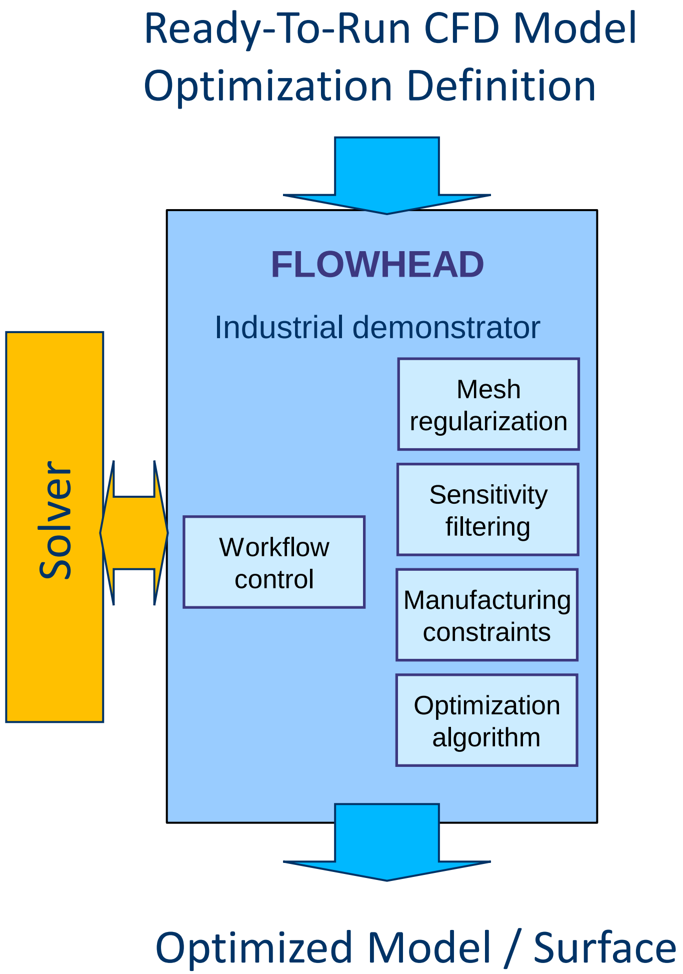


20 years of experience

FLOWHEAD

Industrial demonstrator

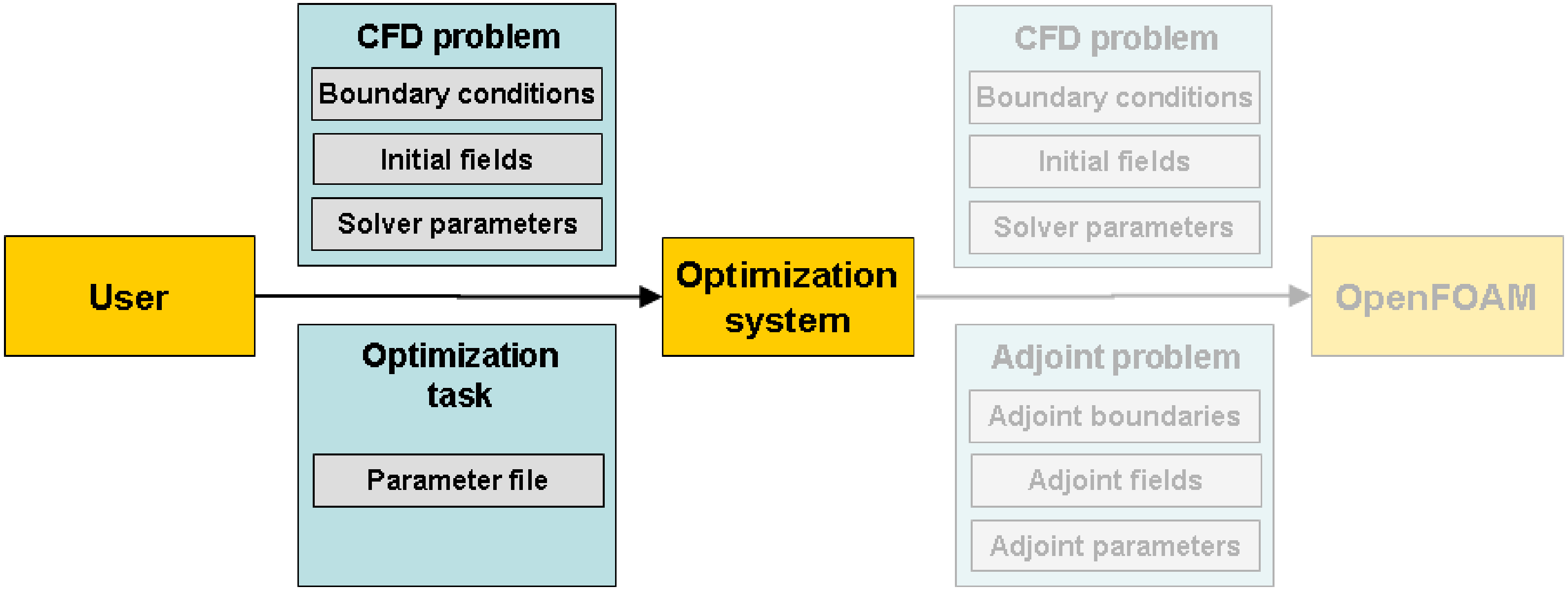
Demonstrator Framework - Advantages



- Adaptable optimization
- Workflow Simplifies testing and validation
- Modules can be developed separately
- Partners can develop modules for the framework
- Defined interfaces
- **Sustainable architecture**

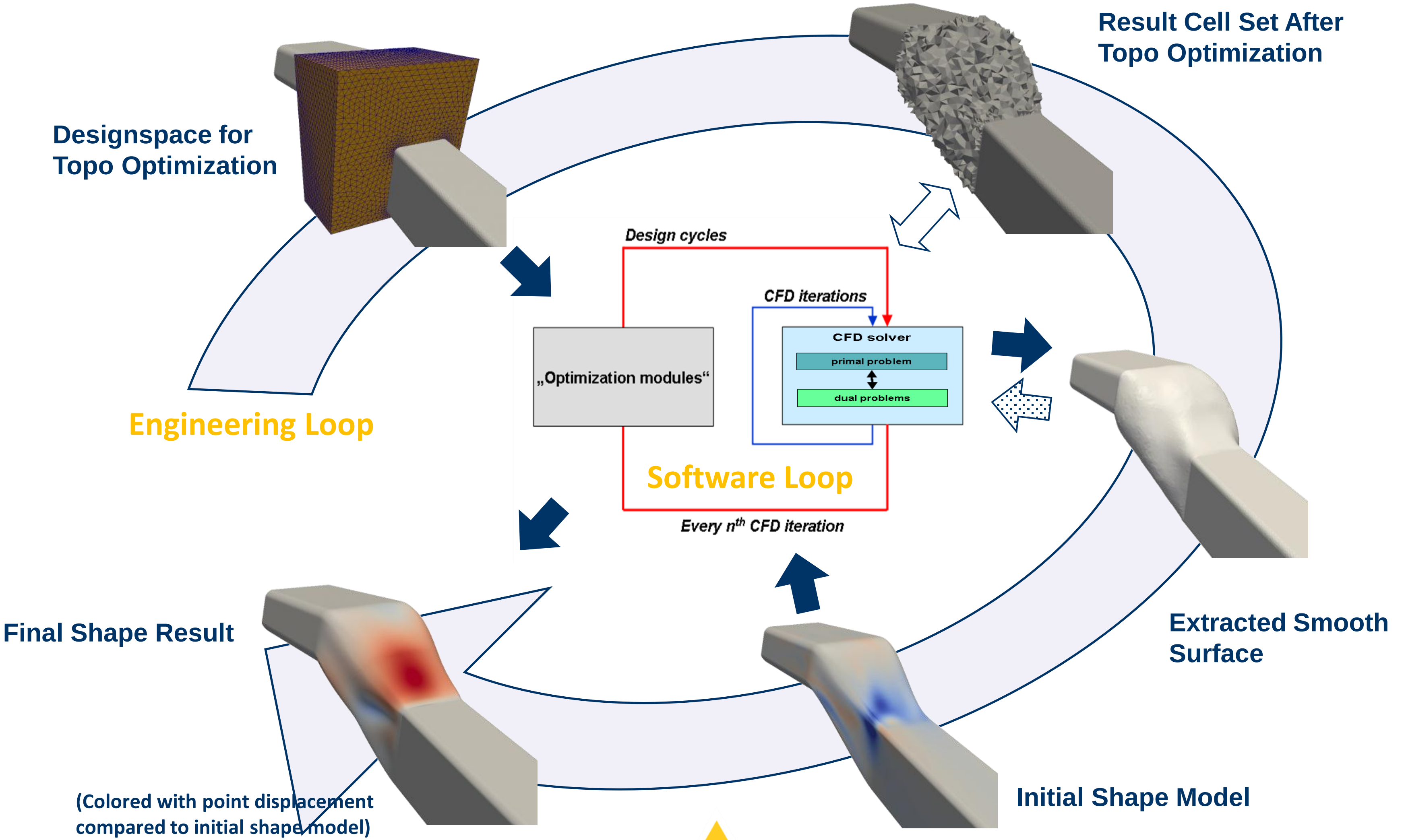
Demonstrator Framework - User friendliness

Continuous Adjoint



- User wants to specify CFD problem and the optimization task
- Optimization system has to create necessary adjoint problem(s)

Demonstrator Framework – Possible Optimization Loop



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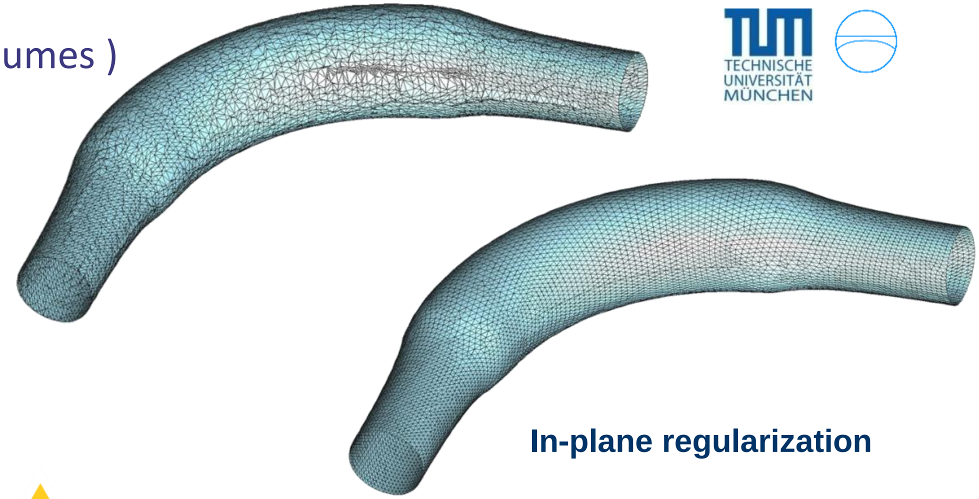
Demonstrator Framework – Capabilities

- Different optimization algorithms
  - Steepest descent (unconstraint)
  - MMA - Method of moving asymptotes (constraint + unconstraint)
- Different filter and regularization methods available
  - In-plane regularization (TU München)
  - Out-of-plane filtering (TU München)
  - Laplace regularization
  - Sigmund filter (for surfaces and volumes)
  - Design - Nondesign transition filter



In-plane regularization

Demonstrator Framework – Objective function and constraints

- Cost functions can be used as objective function

  $\min(\, f(x)\,)$

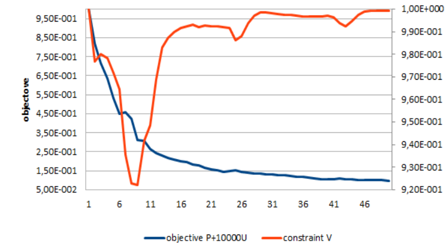
- Cost functions can be used as constraints

  $g(x) \leq g^*$

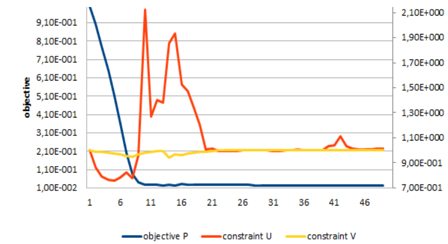
- Cost functions can be combined

  $f(x) = a * f_1(x) + b * f_2(x)$

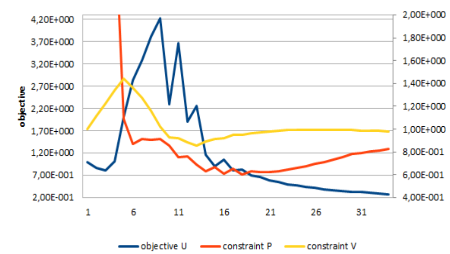
Objective
$min(\,\Delta P + c_1 * U\,)$
Constraint
$V \;\leq\; c_2 \; * V_0$



$min(\,\Delta P\,)$
Constraints
$U \;\leq U^*$
$V \;\leq c_2 * V_0$

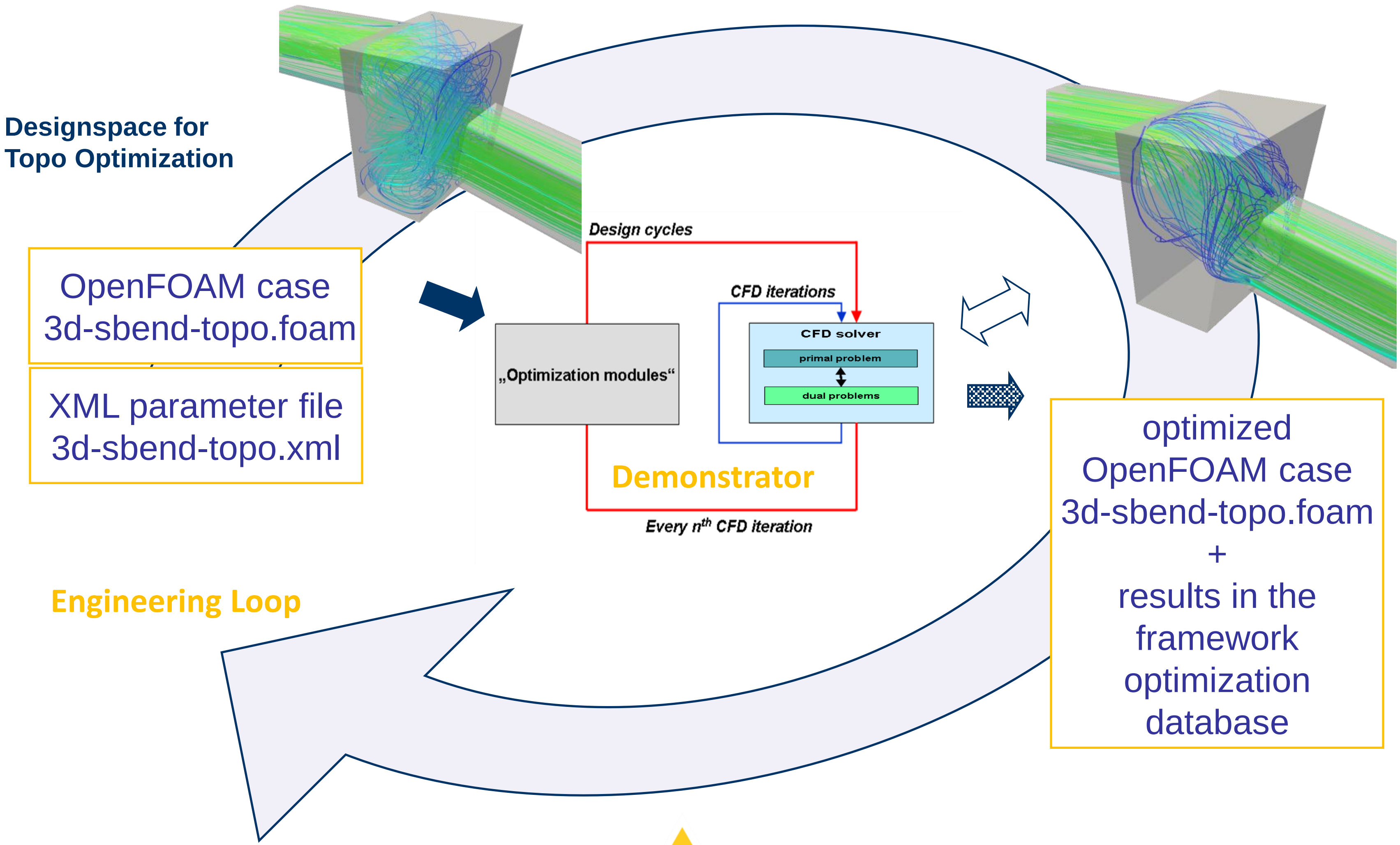


Objective
$min(\,U\,)$
Constraints
$\Delta P \;\leq P^*$
$V \;\leq c_2 * V_0$



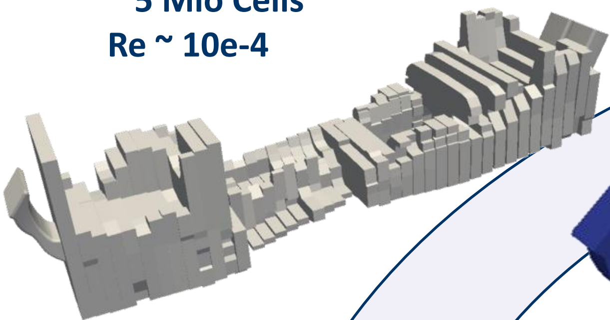
U – Uniformity
V – Volume
ΔP – Total Pressure Loss

Demonstrator Framework – Topology optimization



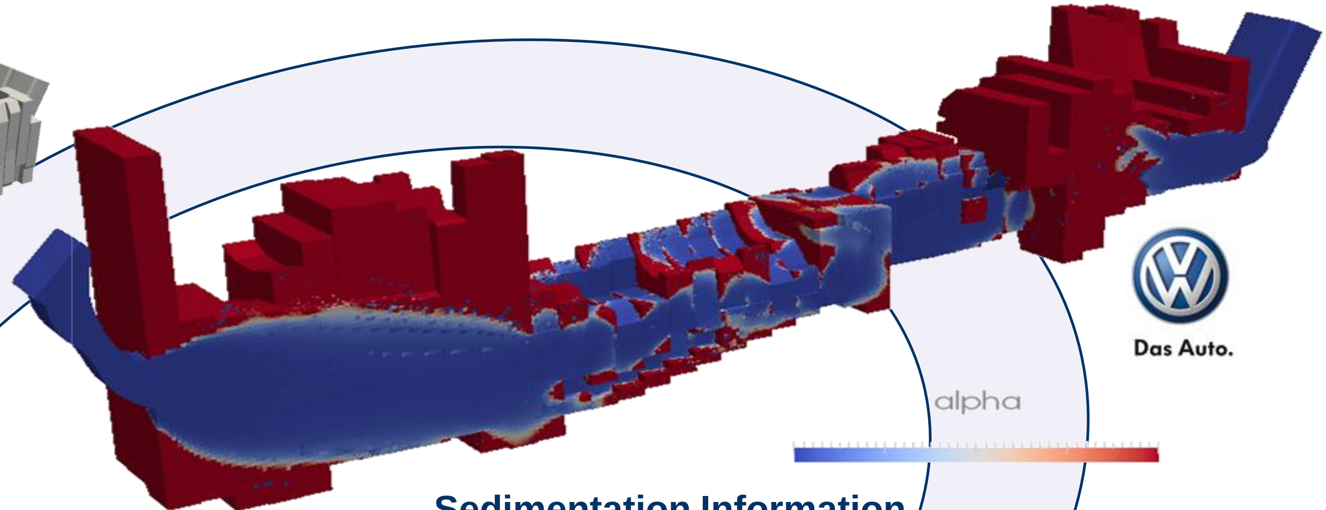
Topology optimization - VW Topo Example

~ 5 Mio Cells
Re ~ 10e-4



Design Space Model

Engineering Loop



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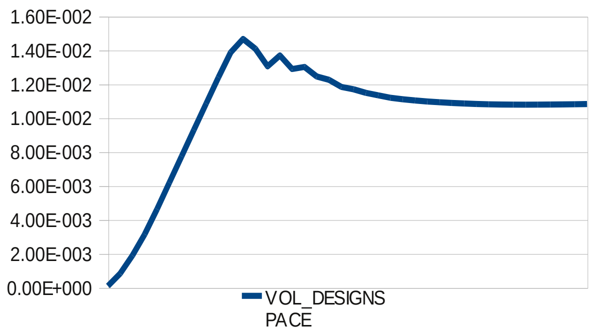
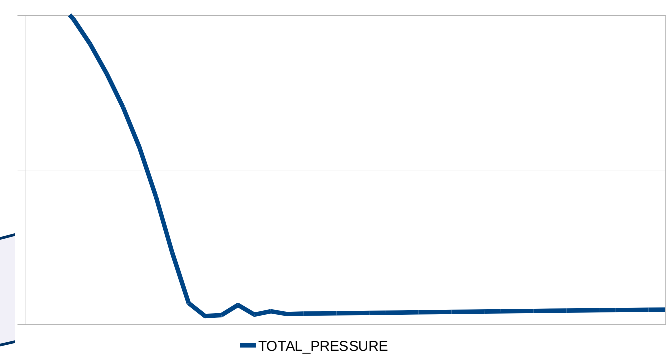
Sedimentation Information

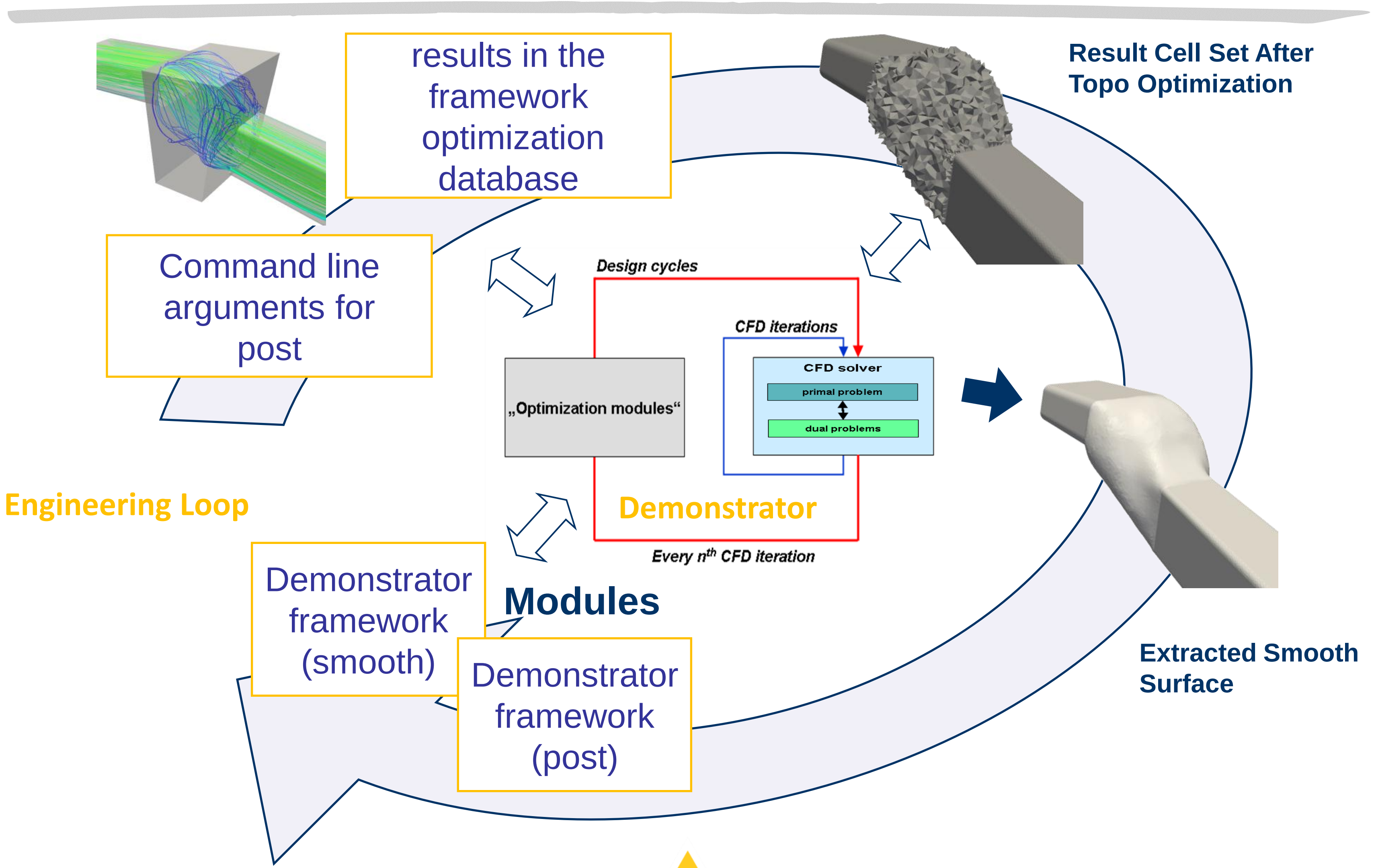


Volume Constraint



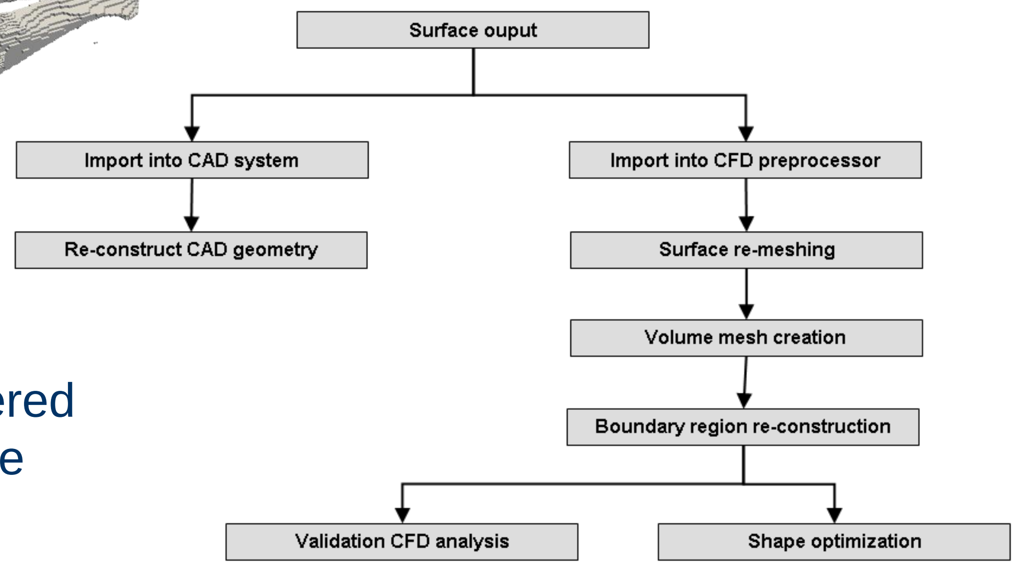
Objective Function

Demonstrator Framework – Result extraction

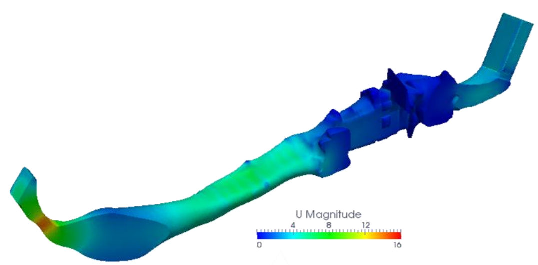


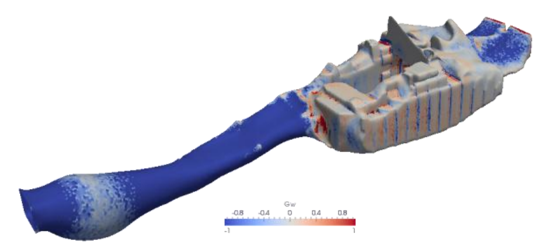
Topology optimization - VW Topo Example

Final Cell Subset After Optimization



The cell set has to be tranfered into a closed smooth surface representation





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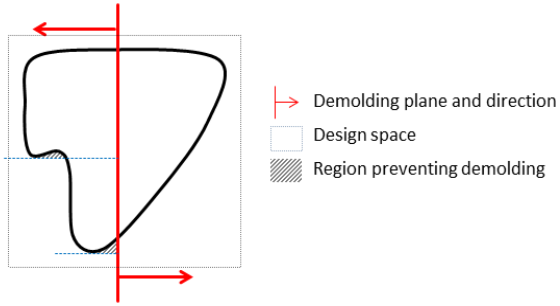
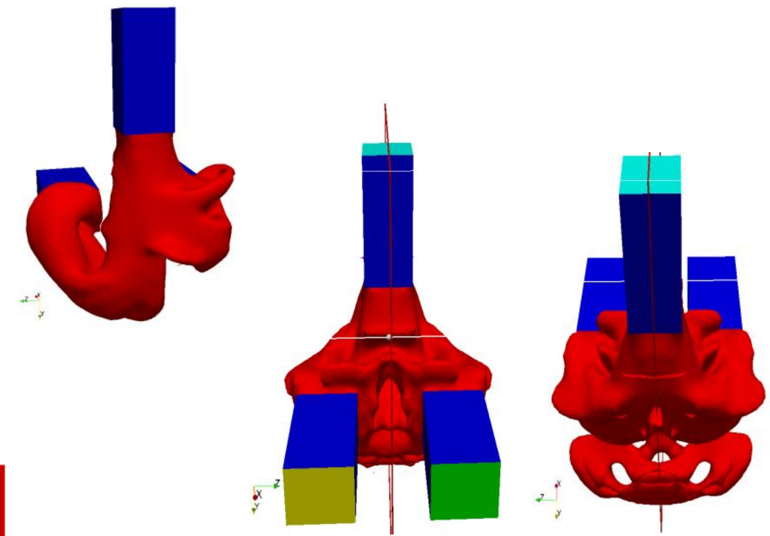
Demonstrator Framework – Manufacturing Constraints for Topological Optimization

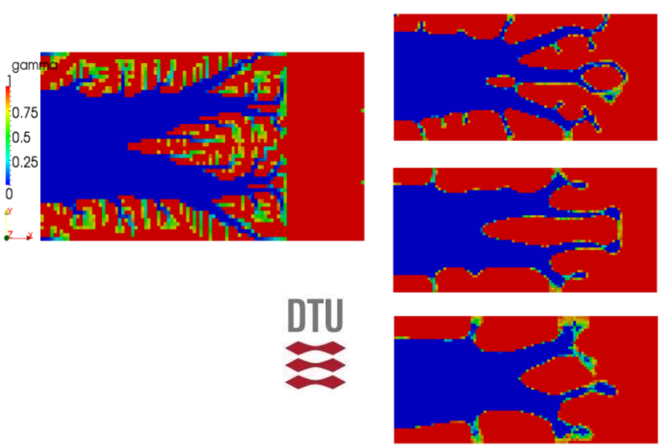
Demolding



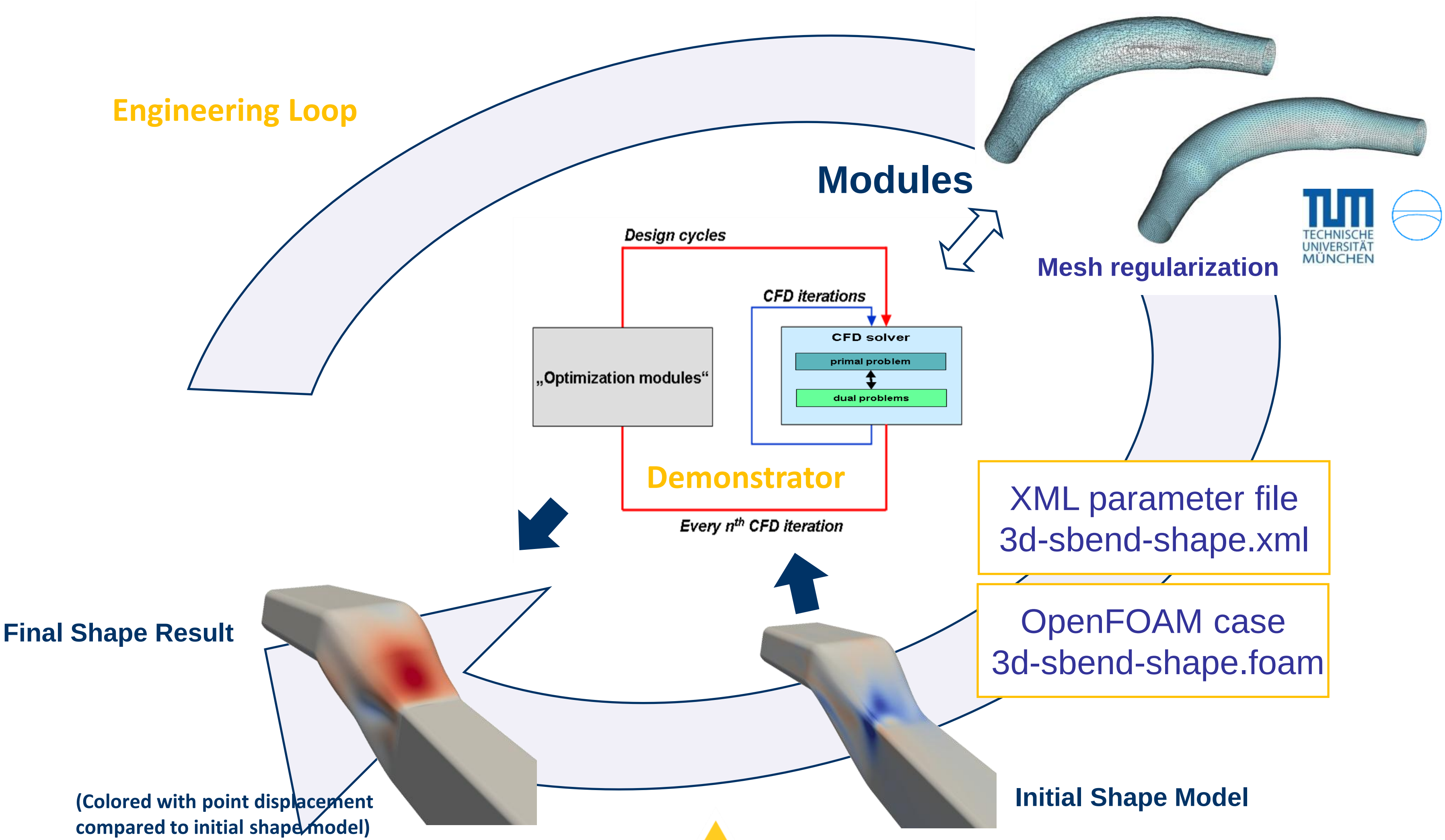
Symmetry



Minimum Member Size



Demonstrator Framework – Shape optimization



Shape Optimization – VW Example

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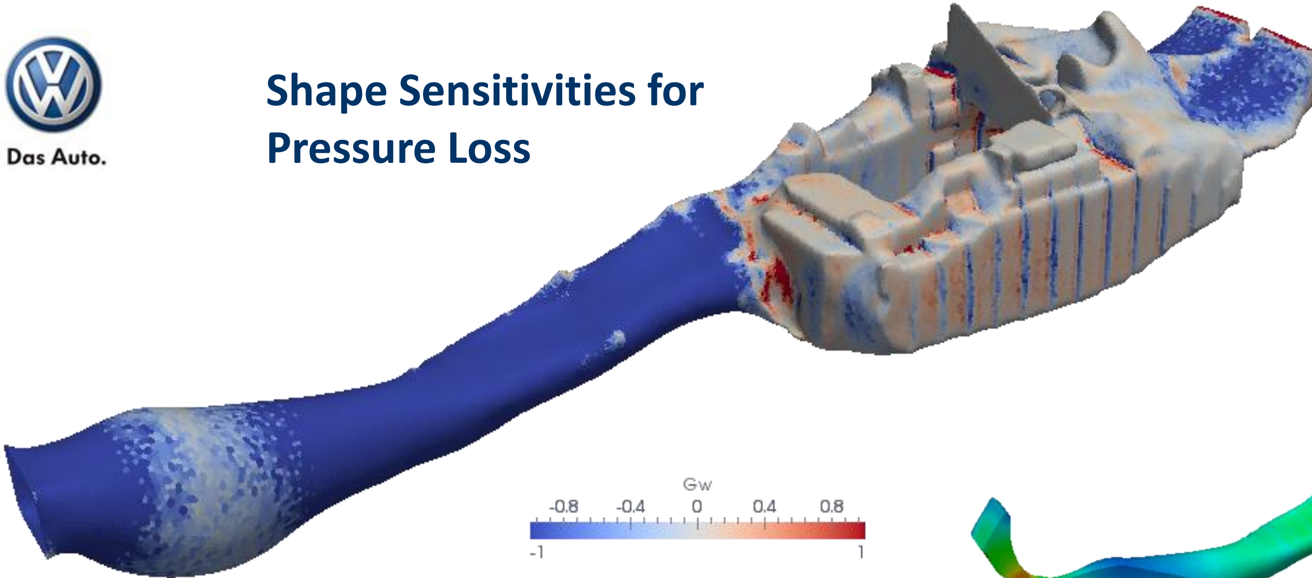
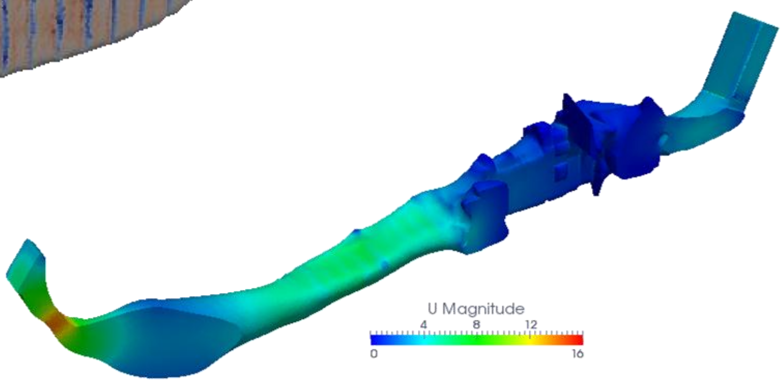
Shape Sensitivities for Pressure Loss





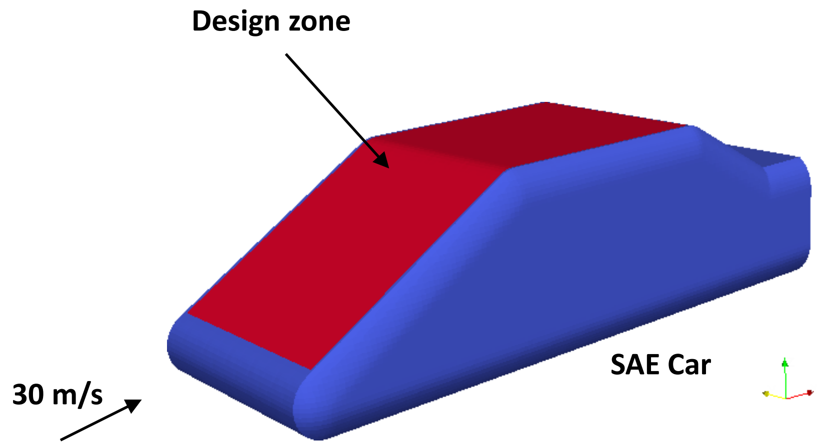
After topological optimization

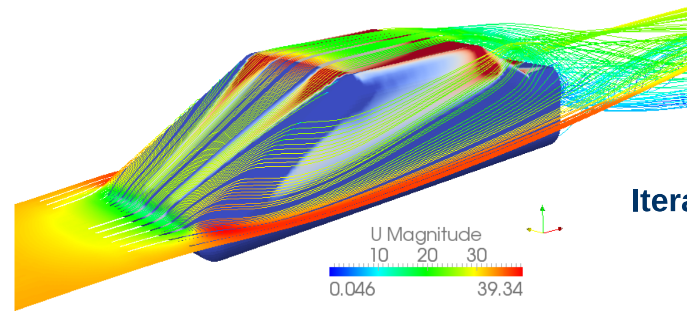
- The extracted STL surface can be used for further shape optimization processes

Optimization of existing products

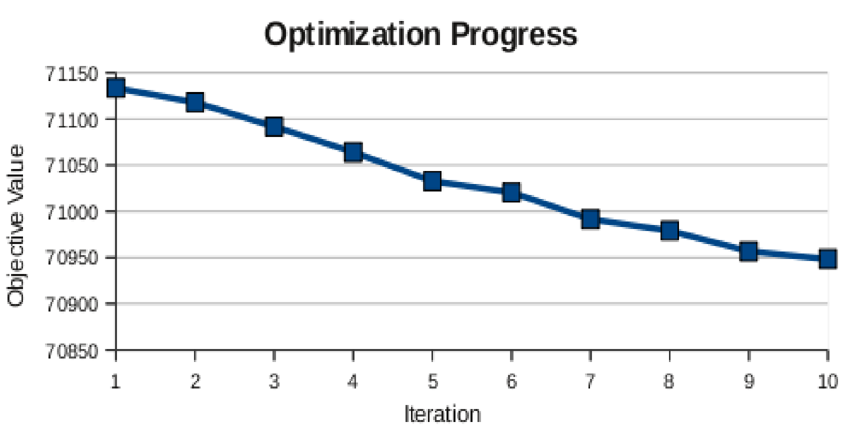
- Existing models can start the optimization loop within this state

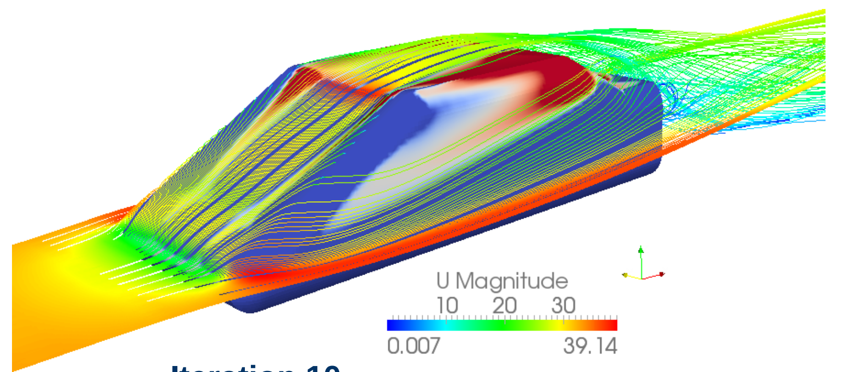
External Shape Optimization – SAE Body Example





Iteration 1





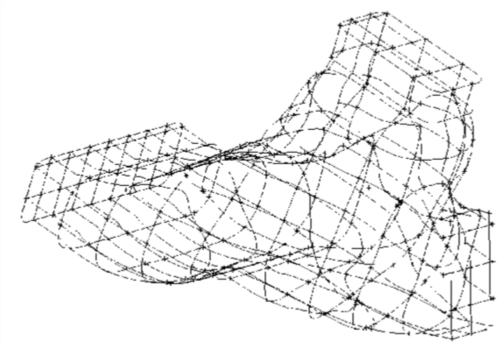
Iteration 10

Optimization with respect to Pressure Loss

Demonstrator Framework – Post-processing

CAD re-construction

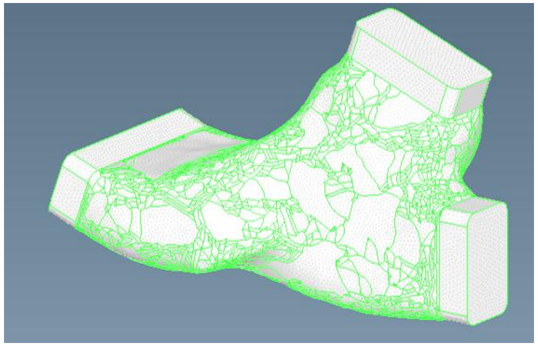
A very important step is how to get the optimized geometry back into a CAD system

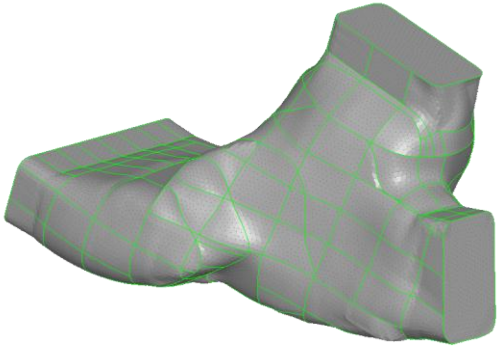


Re-construct based on IGES cuts

IGES re-construct

- The advantage of IGES cuts are big and simple shapes
- Depending on the number of cuts a de-featuring is possible

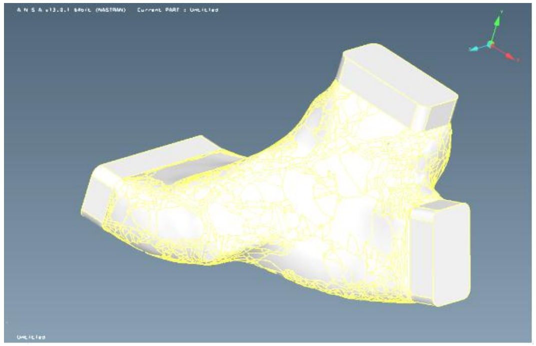




Re-construct based on STL data

STL re-construct

- The shape size depends on the local surface angle and
- All features are kept



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Summary

- **A Demonstrator Framework has been developed that :**
  - Can be used to easily set up an optimization tasks
  - Controls topo and shape optimization processes
  - Takes care about data handling
  - Is open for parallel optimization
  - Supports constraints and manufacturing constraints
  - Provides multiple objective functions
  - Uses Regularization (TUM) and filtering methods
  - Includes different optimization algorithms – MMA and Steepest Descent
  - Provides an OpenFOAM interfaceIs
  - Is modular and open for further developments

Outlook

- **Further development of adjoints**
- **Improvement of optimization algorithms and stability**
- **Advanced mesh regularization for internal mesh**
- **Improvement of sedimentation algorithms**
- **Adding manufacturing constraints – also for shape**
- **Improving CAD back transfer**
- **Adding additional solver interfaces**

- **Sustainable architecture**

Thank you
for your attention