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Comparison of CAD Parameterization and Metamodeling Approach

for Coolant Channel Flow

Potsdam, 29.09.2017

By the courtesy of Rheinmetall Automotive AG & Friendship Systems AG.

Guntermann | Schiefelbein | Wichmann

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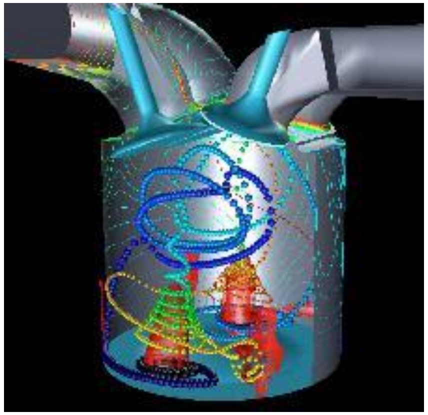
B.Eng

Master student

(mechanical engineering,
third Semester)

Niederrhein University of Applied Sciences, Krefeld

How could we improve a classical workflow?



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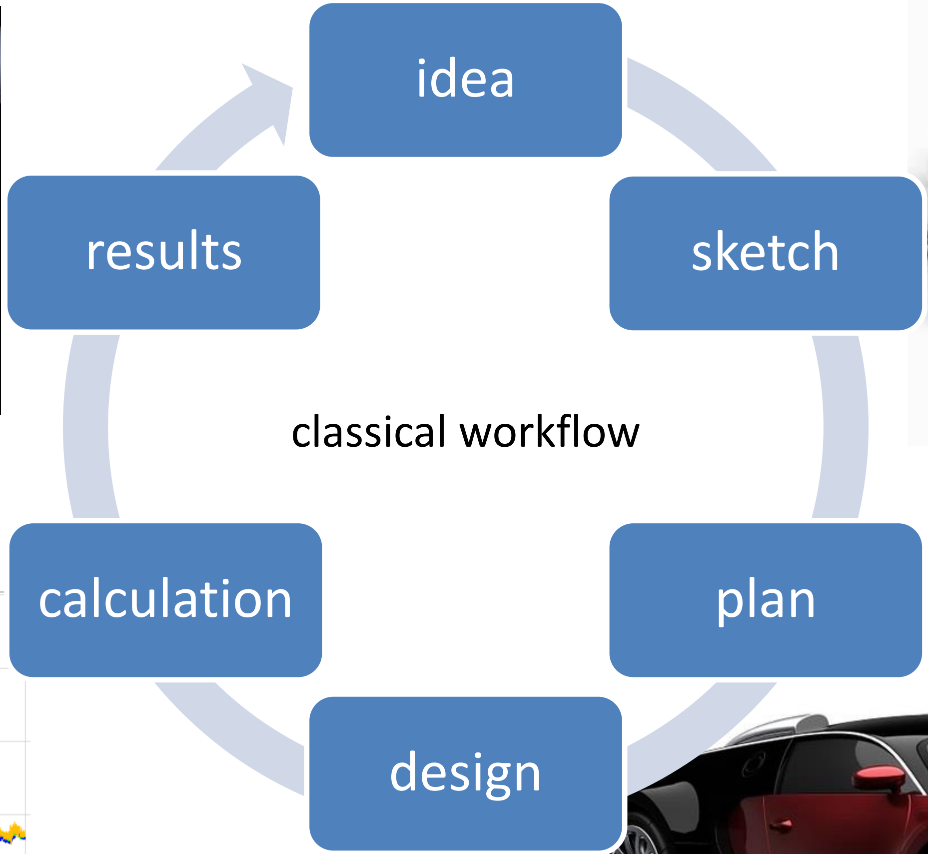

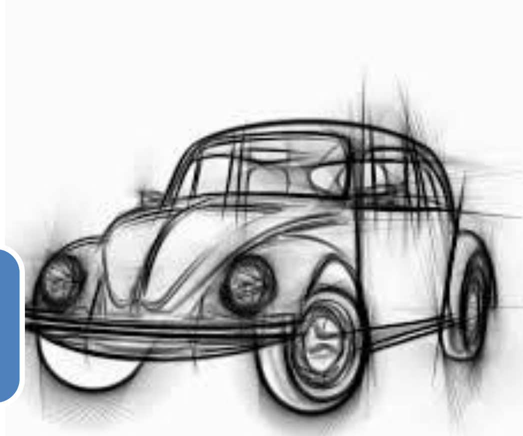

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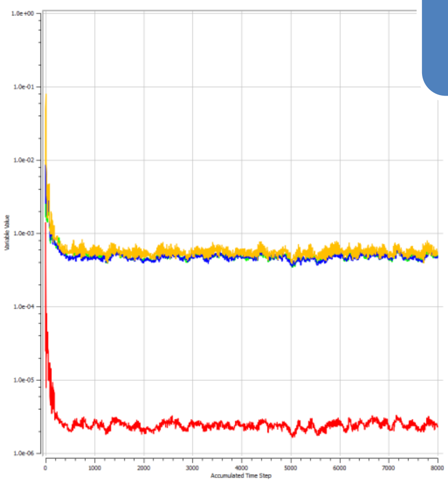

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Outline

- Introduction
- ANSYS-Workflow
- CAESES-Workflow
- Comparison of CAD Parameterization
- Comparison of Metamodeling Approach
- Conclusion and Lessons Learned
- Perspective

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Introduction

Niederrhein University of Applied Science,
first master project

Project team

- Guntermann J. (master student, third semester)
- Schiefelbein V. (master student, third semester)
- Wichmann N. (master student, third semester)

Supervisor

- Prof. Roos

Period of time

- 1/09/2016 to 31/3/2017

Project partner

- FRIENDSHIP SYSTEMS AG, Potsdam
- Rheinmetall Automotive AG, Neuss

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Introduction

Main tasks

- ➢ Compare different CAD parameterizations

  -ANSYS Design Modeler

  -CAESES

- ➢ Compare different metamodel algorithms

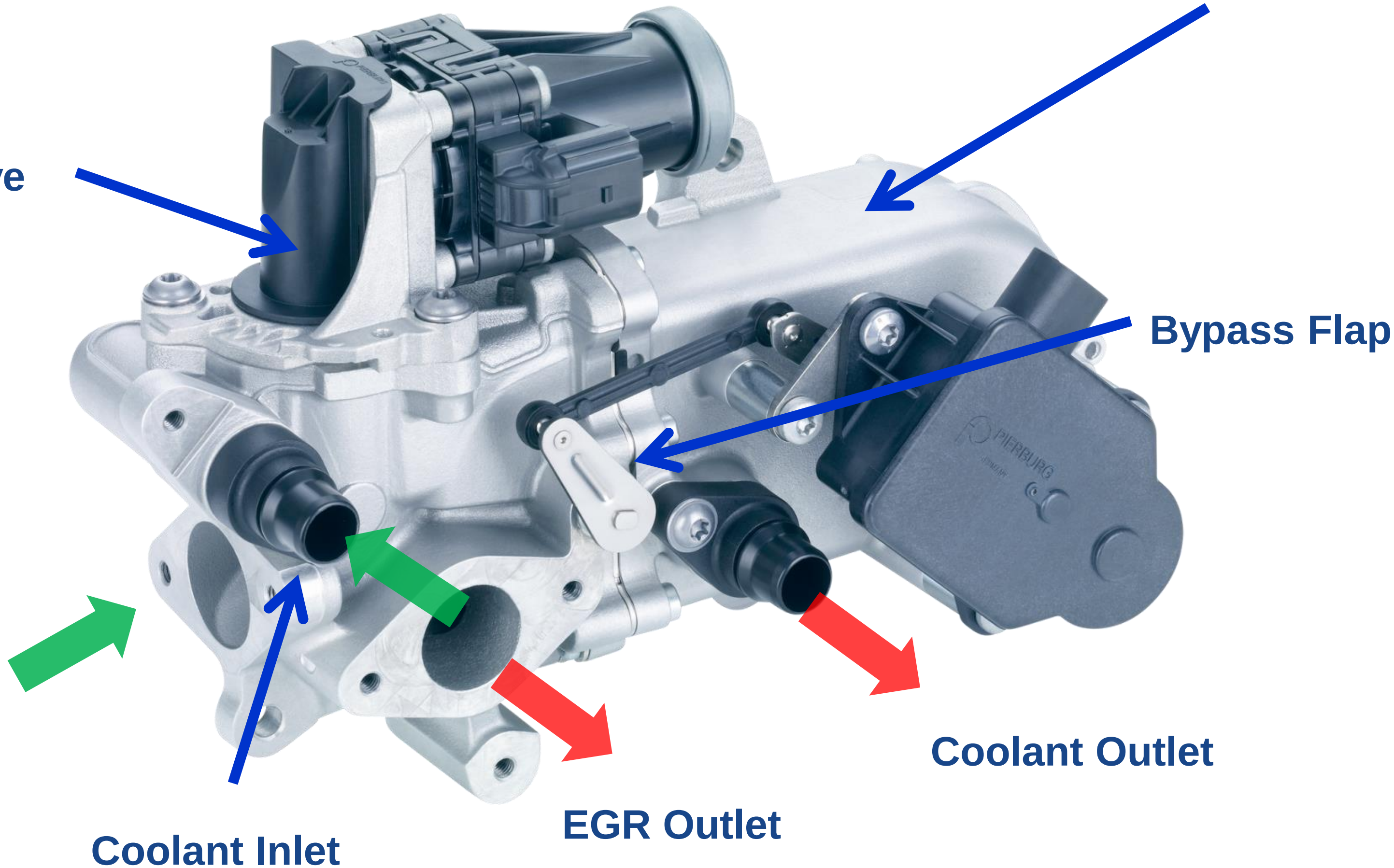
  - OHSM (Optimal Hybrid Surrogate Model)
  - optiSLang

Work packages

- ➢ Create two (fully automated) workflows
- ➢ Make sure that the workflows are similar
- ➢ Identify sensitive parts of the geometry
- ➢ Test new software packages

Introduction

EGR module



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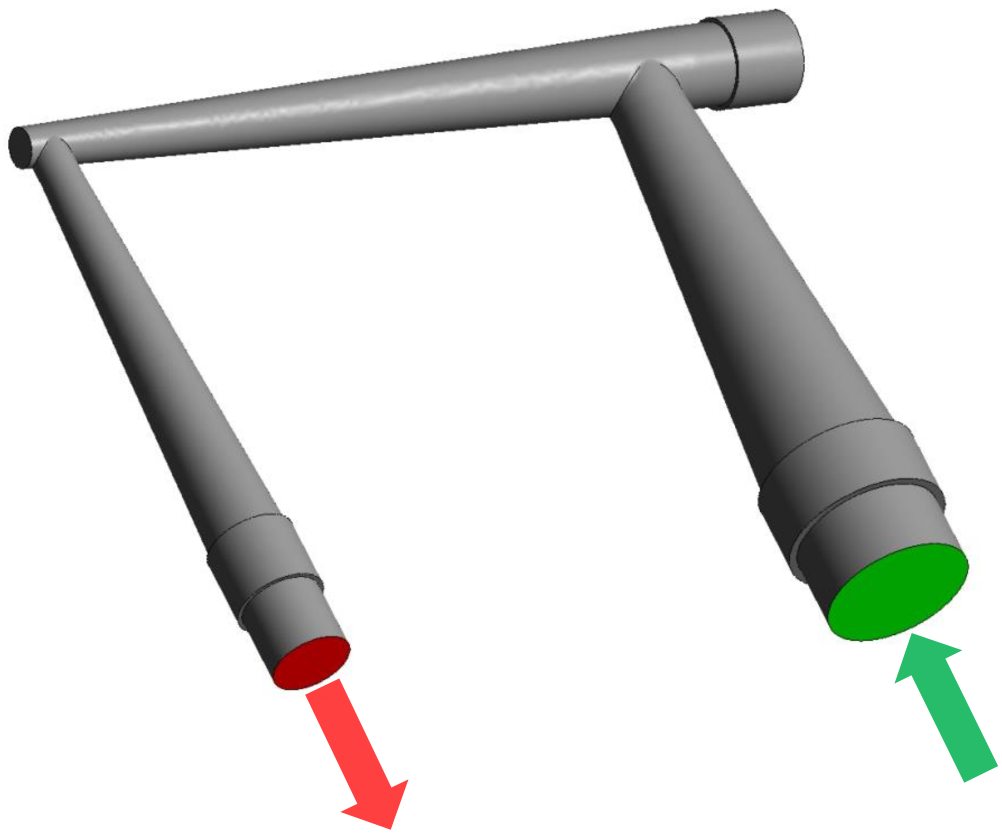
Introduction

CAD model and CFD setup



Boundary conditions	values
Pressure inlet	2.5 bar
Temperature inlet	90°C
Volume flow	4 l/min
Mass flow	=volume flow * density
Wall temperature	200°C
Turbulence model	Shear Stress Transport

Fluid:	Coolant-Water Mix
ρ	1,025 kg/m³
c_p	3,650 K/kgK
η	0.000923 Pas
λ	0.0445 W/mK

Introduction

Example for an automated Workflow

start

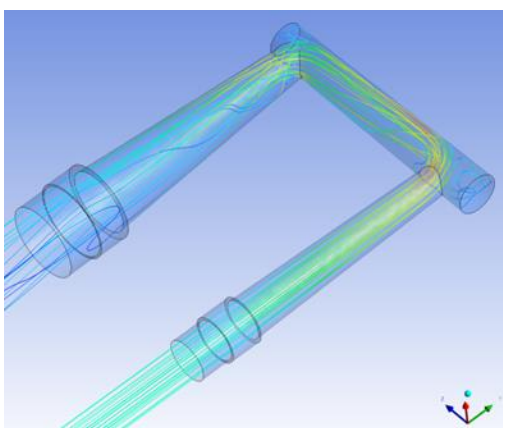
CAD-Tool
(CAESES)

results

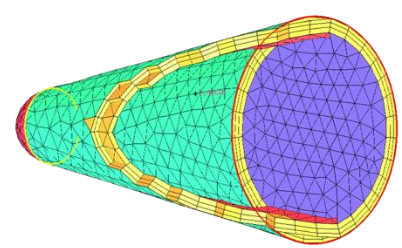
Optimization
(optiSLang)

Automated
workflow

Mesh editor
(ICEM)



Solver
(CFX)



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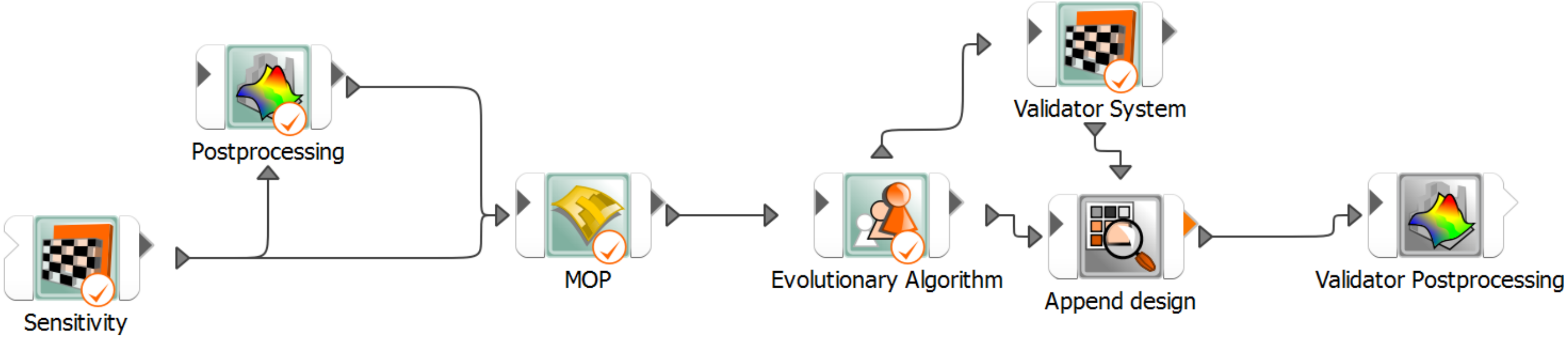
Introduction

optiSLang

- Manage different jobs
- Connect software packages
- Create sampling plan
- Analyze output files
- Create metamodels (MOP)
- Run optimization
- …

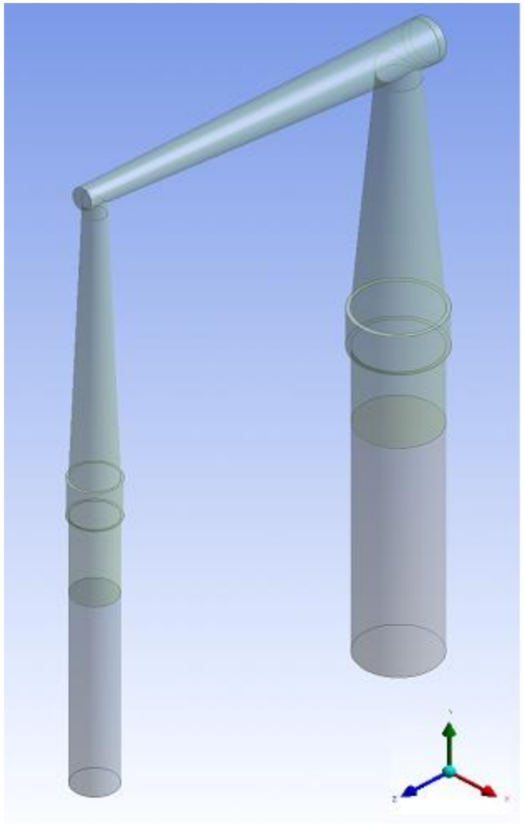
CoP (Coefficient of Prognosis)

- How accurate can the metamodel represent the real simulation results?
- Measure for estimation of prediction quality
- Indicates the amount of variance contribution coming from input variation
- Higher values are better (ideal=100%)



ANSYS-Workflow

ANSYS Workbench 17.2, optiSLang 5.2



Parameterized model in ANSYS

- Based on direct parametrized diameters etc. to define cross-sections
- In total 40 parameters, 22 active in use
- Connection via plugins

Parameters

- Diameters
- Lengths
- Angles

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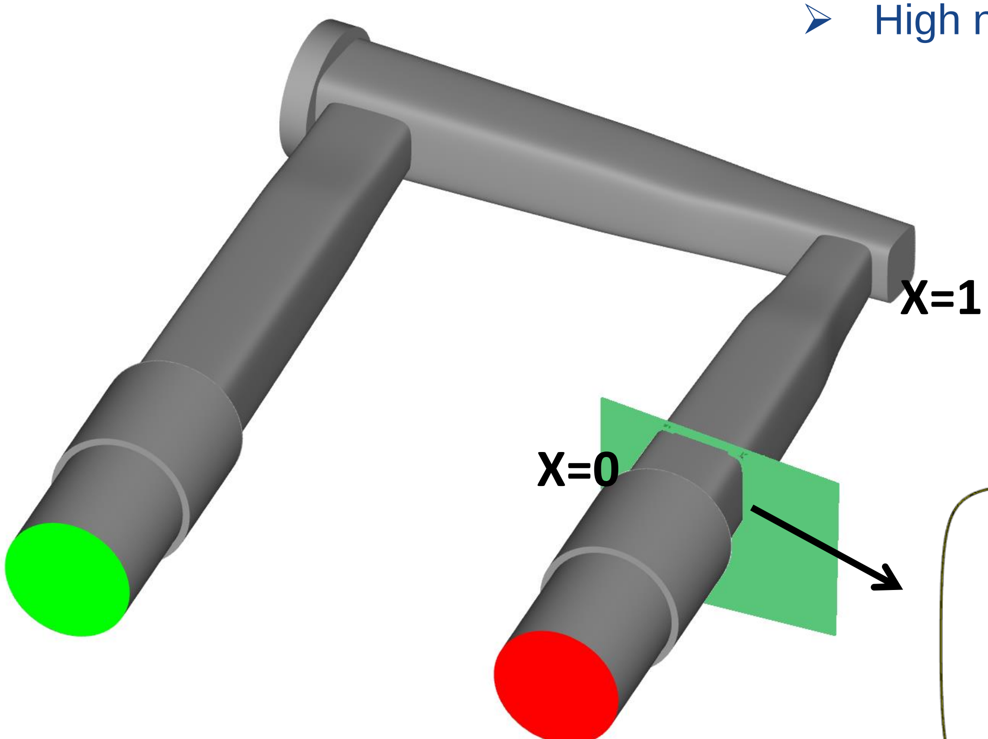
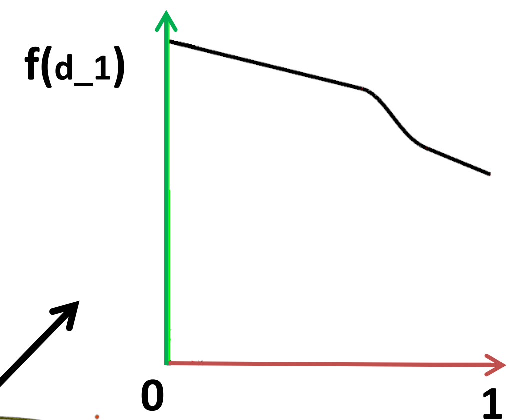
CAESES-Workflow

CAESES 4.1,
ANSYS Workbench 17.2,
optiSLang 5.2

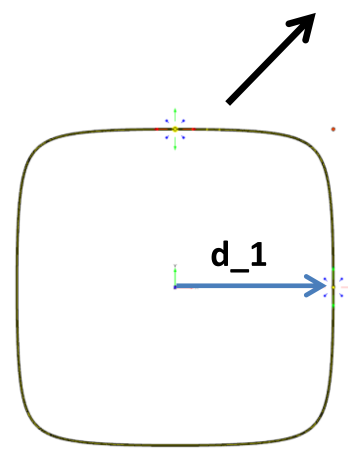
- Based on one variable cross-section
- Parameters replaced by functions
- Parameterized supporting points
- High number of parameters (65)



Parameterized model with cross-section



Function for parameter d_1



Cross-section with parameter d_1

Comparison of CAD Parameterization

CAESES compared with ANSYS Design Modeler

ANSYS Design Modeler

- Based on several variable cross-sections
- Diameters etc. direct parametrized
- 22 active parameters

CAESES

- Based on one parametrized cross-section
- Parameters replaced by functions
- Parameterized supporting points
- High number of parameters (65)

- Both CAD geometries can represent the original which was given by the company
- Intuitive changes are possible
- No failed runs

Comparison of Metamodeling Approach

CoP's for ANSYS workflow, 22 parameters, 120 designs

optiSLang

in %	obj1	obj2
parameter 1		30,8
parameter 2	51,9	16,7
parameter 3		11,9
parameter 4	17,3	11,3
parameter 5	43,1	8,4
parameter 6	21,1	
parameter 7	39,2	11,9
parameter 8		17,3
parameter 9		3,7
parameter 10		1,7
parameter 11		4,6
Total	99,7	88,4

OHSM

obj1	obj2
	33
51	25
9	18
41	7
13	
38	7
	5
	5
97	96

Comparison

- Similar high values
- Mostly the same parameter identified
- OSHM more conservatively, uniquely

Obj1 and obj2 represent the objectives

Parameter1 to 11 are e.g. diameter etc.

	objective 1	objective 2
OSL	99.7	88.4
OHSM	97	96

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Comparison of Metamodeling Approach

CoP's for CAESES workflow, 65 parameters, 200 designs

optiSLang / OHSM

in %	optiSLang obj1	optiSLang obj2	OHSM obj1	OHSM obj2
parameter 1		10,2		12,0
parameter 2		10,6		9,0
parameter 3	2,5	9,7	4,0	15,0
parameter 4	1,5	1,6	2,0	3,0
parameter 5	0,8	0,8	1,0	2,0
parameter 6	1,6	2,8	5,0	3,0
parameter 7	6,2	13,9	6,0	16,0
parameter 8	1,2	2,5	3,0	1,0
parameter 9	3,9	3,9	4,0	3,0
parameter 10		1,1		1,0
parameter 11	5,3	8,6	5,0	6,0
parameter 12	6,3	1,6	7,0	1,0
parameter 13	0,7	2,5	2,0	2,0
parameter 14	3,5	0,4	3,0	
parameter 15	0,6		2,0	
parameter 16	2,5		4,0	
parameter 17	1,6		4,0	
parameter 18	1,7		3,0	
parameter 19	2,3		3,0	
parameter 20	7,3		10,0	
parameter 21	1,3		1,0	
parameter 22	9,4		10,0	
parameter 23			1,0	
parameter 24	6,7		7,0	
parameter 25				1,0
parameter 26			1,0	
parameter 27		9,7	2,0	9,0
parameter 28	3,7	0,3	4,0	2,0
parameter 29	1,6	3,3	1,0	6,0
parameter 30			4,0	
Total	71,2	82,8	90,0	95,0

optiSLang-ANSYS

in %	obj1	obj2
parameter 1		30,8
parameter 2	51,9	16,7
parameter 3		11,9
parameter 4	17,3	11,3
parameter 5	43,1	8,4
parameter 6	21,1	
parameter 7	39,2	11,9
parameter 8		17,3
parameter 9		3,7
parameter 10		1,7
parameter 11		4,6
Total	99,7	88,4

Comparison

- OHSM reaches higher values
- Mostly the same parameter identified
- Compared to ANSYS now 9 parameter (obj2) modify the same geometry parts as 3 parameter before. (But now more accurate)

	objective 1	objective 2
OSL	71.2	82.8
OHSM	90.0	95

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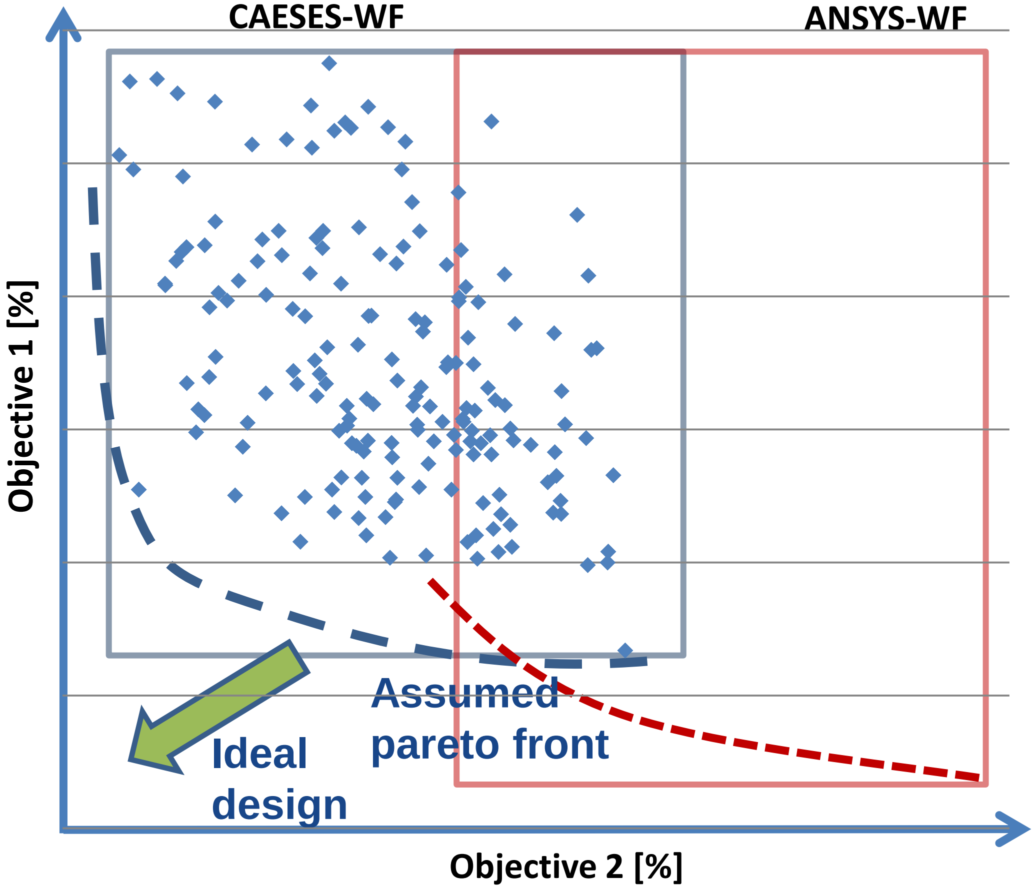
Comparison of Metamodeling Approach

Response spectrum (DoE, Sensitivity Analysis)

(ANSYS: 120 designs, CAESES: 200 designs)



Possible reasons for deviation

- Higher flexibility (CAESES)
- Different mesh editors
- Different space of parameters

The response spectrum of the CAESES-Workflow seems to be more promising

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Comparison of Metamodeling Approach

Response spectrum (DoE, Sensitivity Analysis)

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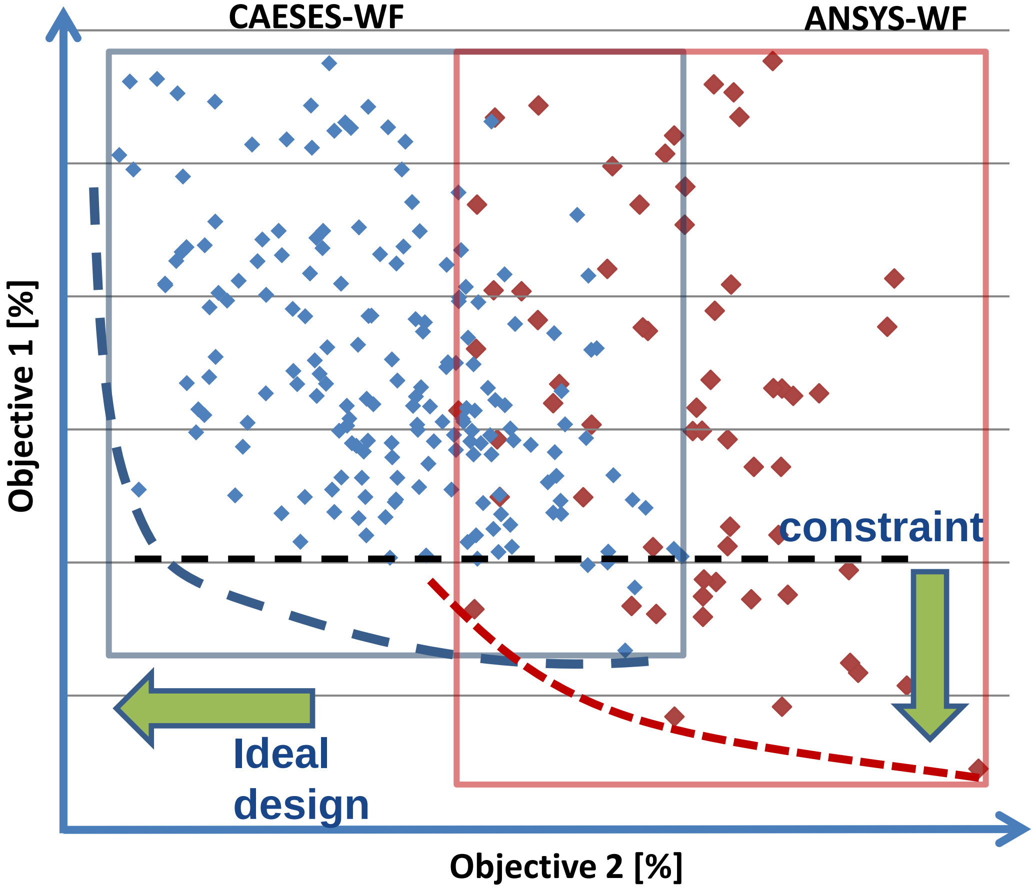


Preparation for optimization

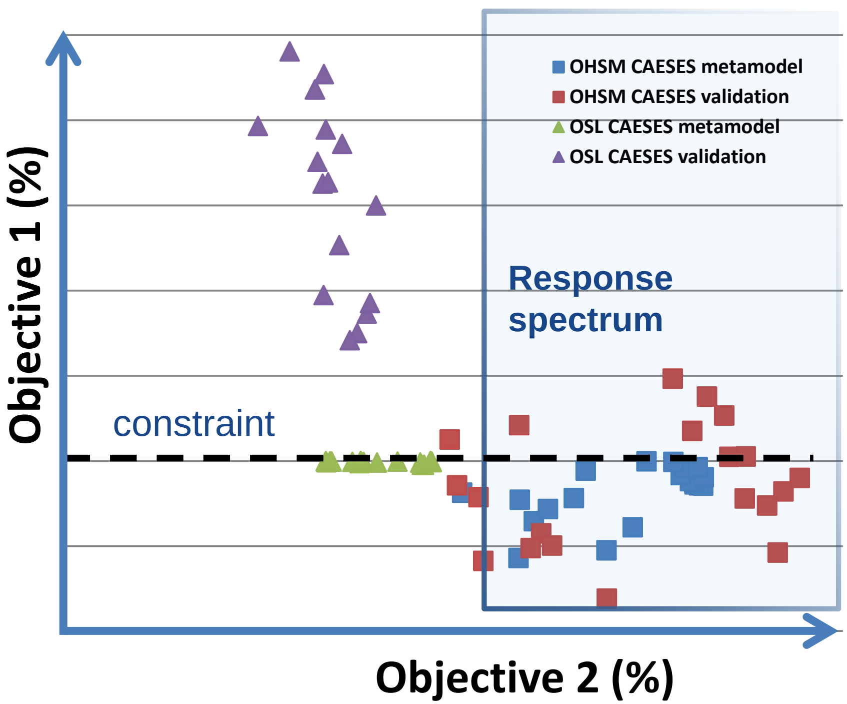
- Target functions:
  min(objective 2)
  constr(objective 1)
- Evolutionary algorithm on MOPs
- Use only the CAESES-WF
- Validate best 20 designs

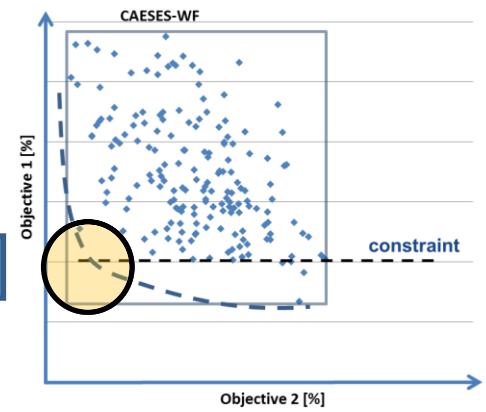
Challenge

- Objective at the bounds of response spectrum
- Low number of designs feasible

Comparison of Metamodeling Approach

Validation of the metamodels for CAESES (best 20 designs)





Relative error to validation / metamodel	Deviation objective1	Deviation objective2
OptiSLang (CoP)	45.19 % (71.2%)	3.28 % (82.8%)
OHSM (CoP)	12.05 % (90%)	3.22 % (95%)

Results

- Feasible designs with lower objective 2 than response spectrum
- OptiSLang gets inaccurately at the bounds of the response spectrum

Comparison of Metamodeling Approach

optiSLang without and with OHSM

optiSLang

- High values for coefficients of prognosis for ANSYS workflow (22 parameters, 120 samples, worst CoP 88.4%)
- Lower values for CoP's and bad validation for CAESES Workflow (65 parameters, 160 samples, worst CoP 71.2%, validation showed higher deviations between prognosis and CFD results)

optiSLang with OHSM metamodel

- High values for coefficients of prognosis for ANSYS Workflow (96% and 97%)
- Higher values for CoP's (90% and 95%) and successful metamodel validation

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Same geometry regions were identified as important for fluid flow

Conclusion and Lessons Learned

CAD Parameterization

- Creating models based on functions allow to manipulate geometry intuitively afterwards
- Higher flexibility with more parameters could be proved
  (Not possible in such a way with ANSYS)

Metamodeling

- Same regions were identified as important for fluid flow by both metamodels
- Both metamodels deliver high CoP's for a low number of parameters
- For higher number of parameters new metamodels are necessary

Possible reasons for deviations / uncertainties

- Different meshing tools were used
- Different number of grid points for the meta-models
- A validation for the ANSYS meta-model has to be added

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Perspective

CAD Parameterization and Metamodeling Approach

- Advanced metamodels are needed for more complex geometries
- Workflow can be fitted to use other CAE applications
- Lessons Learned should be considered in the next steps

[8]

Any Questions?

Thank you for your attention

Contact:

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[9]

Sources

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