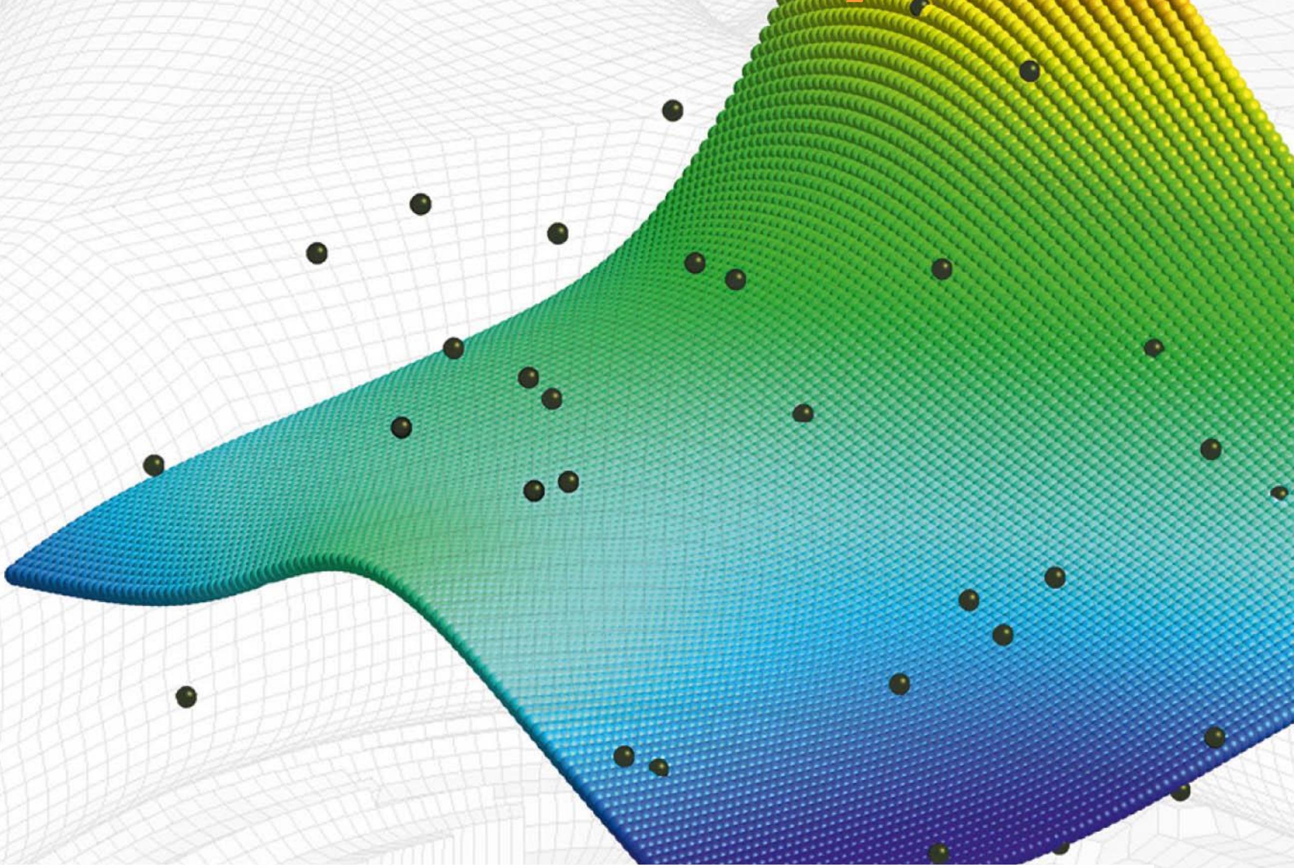
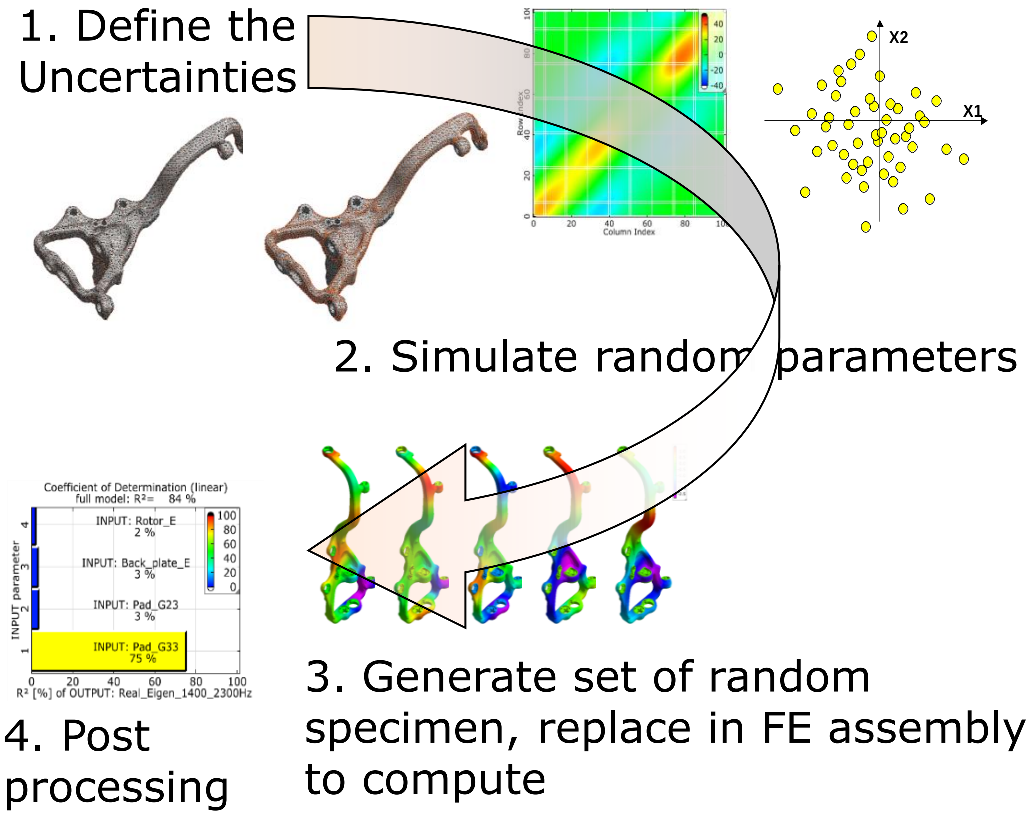
Robust Design Optimization examples automotive industry



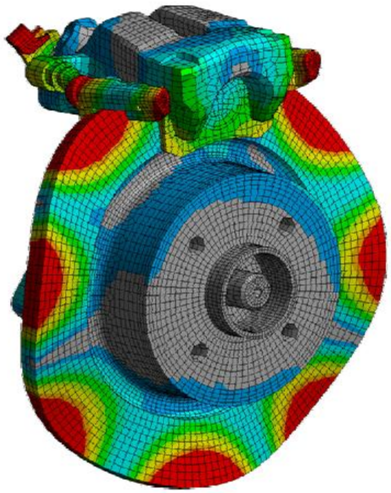
RDO of brake systems

Investigating and optimizing the NVH performance of brake systems answering the question: How does material and geometric scatter influence the brake noise performance ?

- Consideration of material and geometry scatter
- CAE-Solver: NASTRAN, ABAQUS, ANSYS
- Up-to-date robustness evaluation have 20 ..30 scattering variables
- Started 2007 with Robustness evaluations
- Since 2010 extension to automatic robust design optimization using shape function for geometry optimization

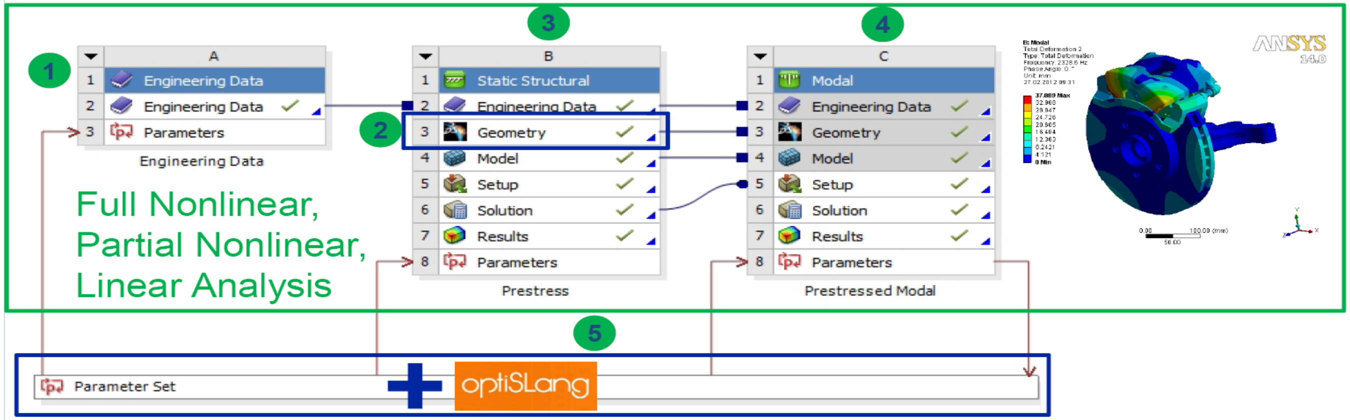


Modern Parametric Process for Brake-Squeal Simulation

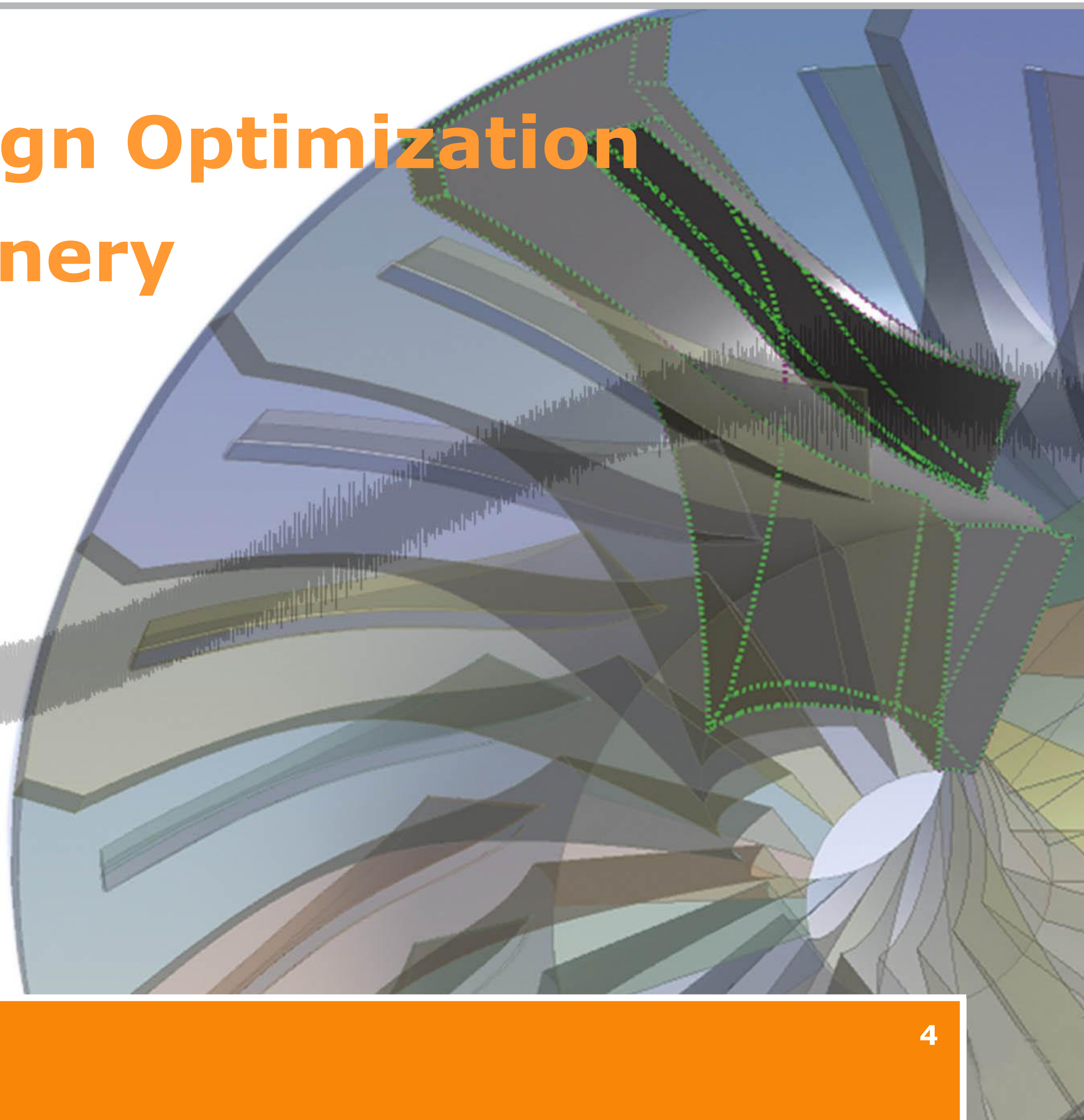


- Brake is an **important and complex, safety and performance** component in automobile.
- NVH field **complaints and warranty costs** as well as permanently **increase in the customer requirements and targets**
- ANSYS Workbench parametric **geometry** modeling functionality helps in establishing a **Simulation Driven Product Development for robust Brakes**

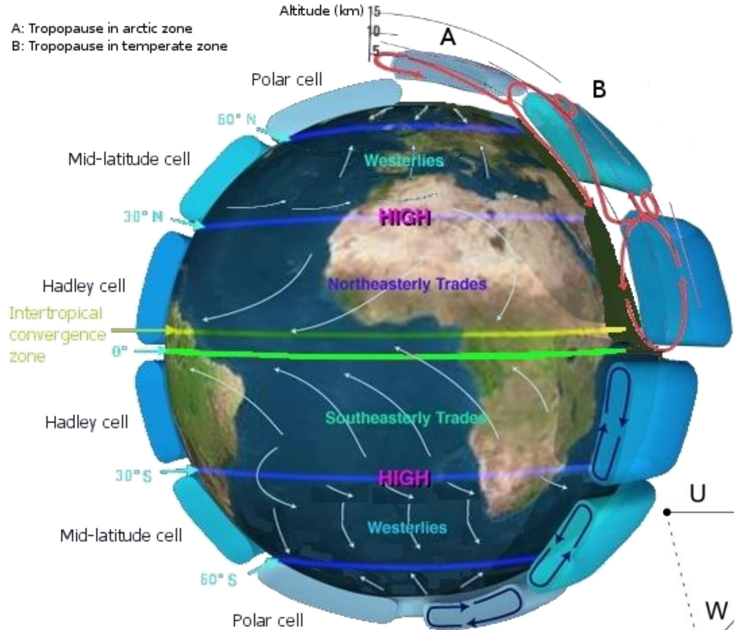
ANSYS Workflow for **Parameterized** Brake Squeal Simulation

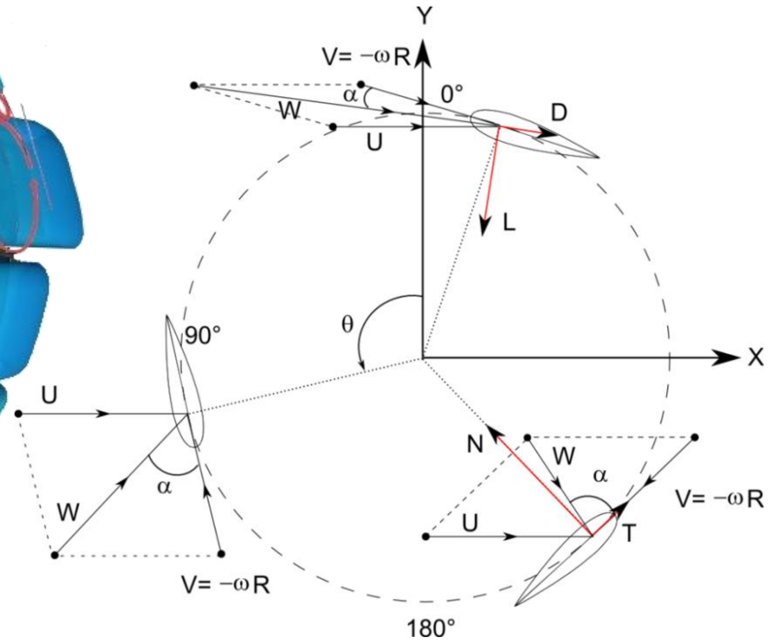


Robust Design Optimization Turbomachinery



Introduction





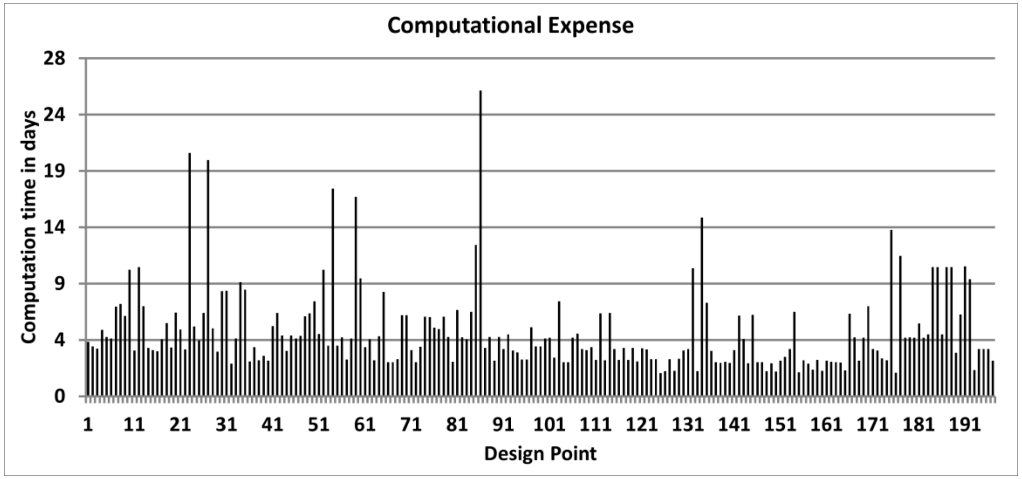
Advantages of Vertical Axis Wind Turbines (VAWT):

- Lower cost compared to horizontal axis wind turbines
- Independent of wind direction
- Good efficiency for lower wind speeds

Motivation

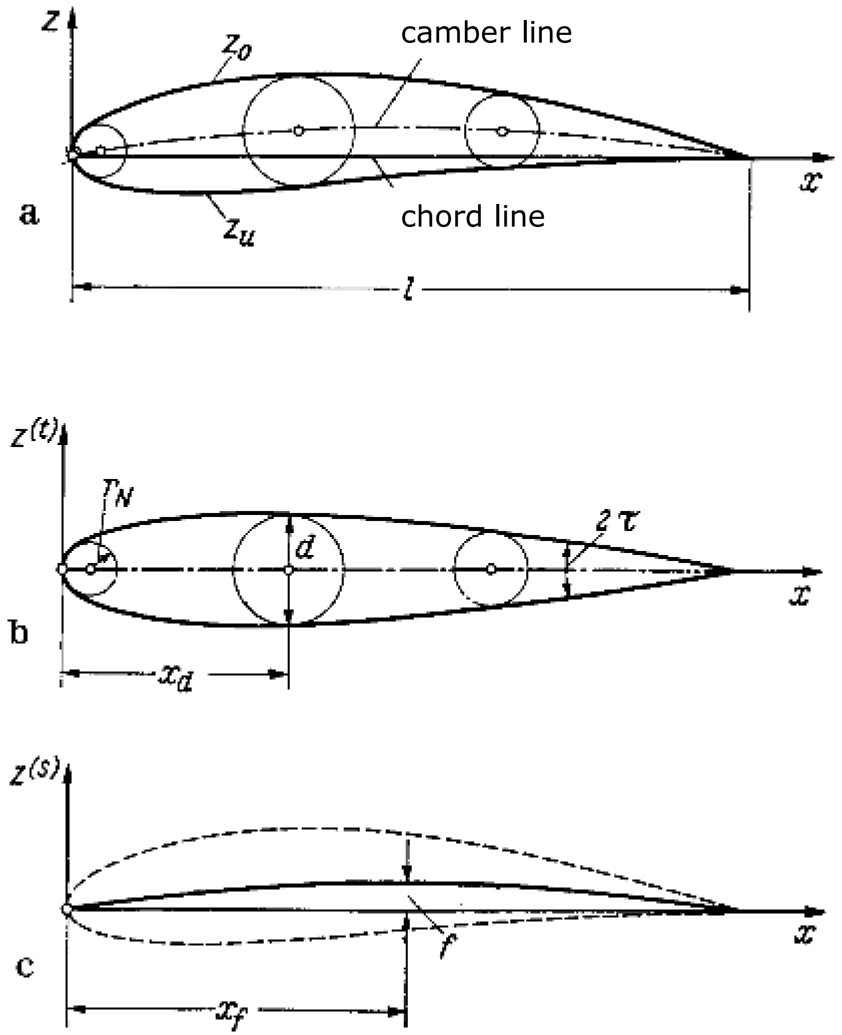
- Prediction with analytical methods is very vague
  → **CFD approach needed**
- Unsteady flow → Transient simulations are required
- Large scale machinery → High grid size

→ **High computational expense**



Solution: ***A high-quality metamodel admits efficient optimizations!***

Modelling

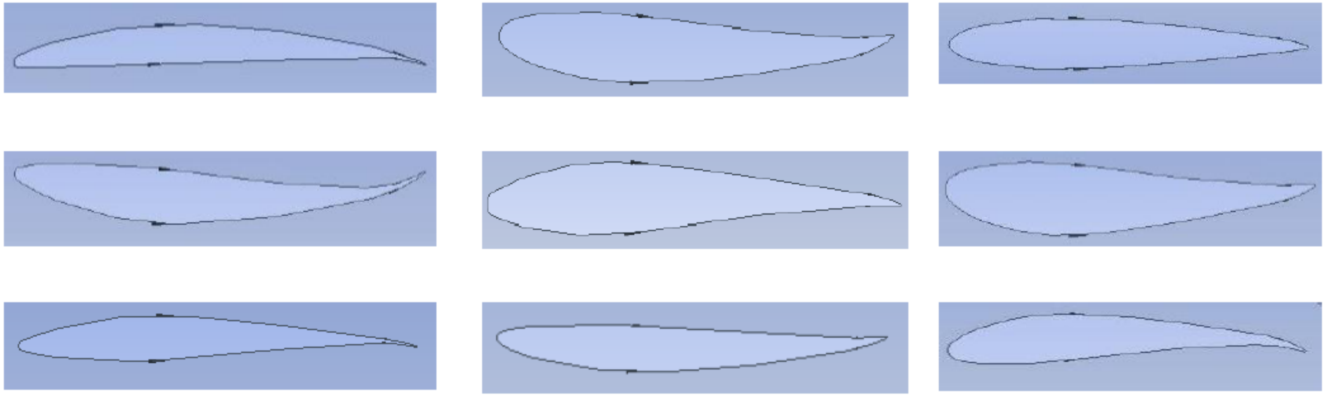


Parameterization according to Aerofoil Theory:

- Relative thickness $\frac{d}{l}$
- Relative camber $\frac{f}{l}$
- Relative distance of maximum thickness from the leading edge $\frac{x_d}{l}$
- Relative distance of maximum camber from the leading edge $\frac{x_f}{l}$
- Relative leading edge radius $\frac{r_n}{l}$
- Relative trailing edge radius $\frac{r_h}{l}$

Modelling

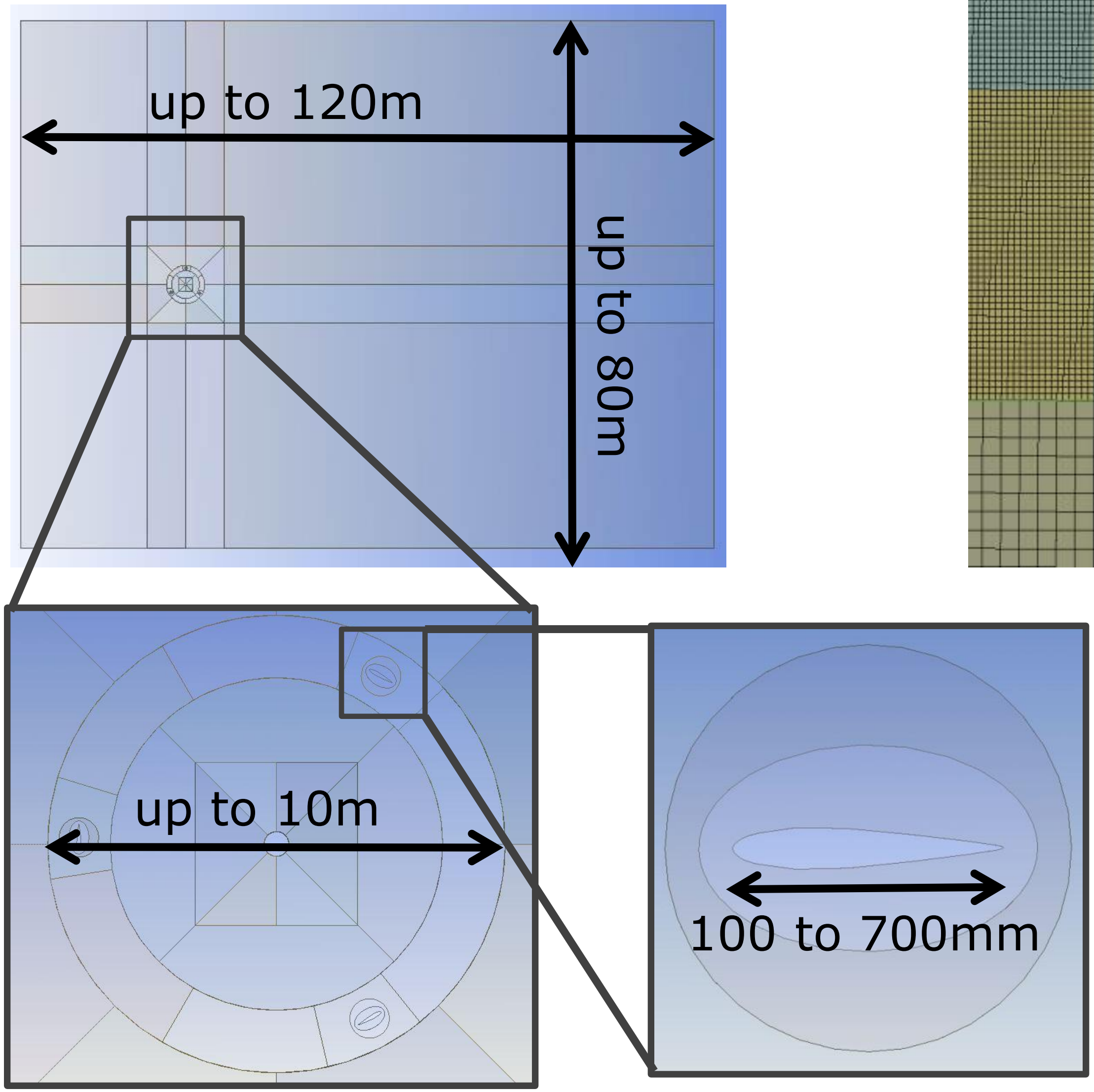
Variation of the aerofoil geometry

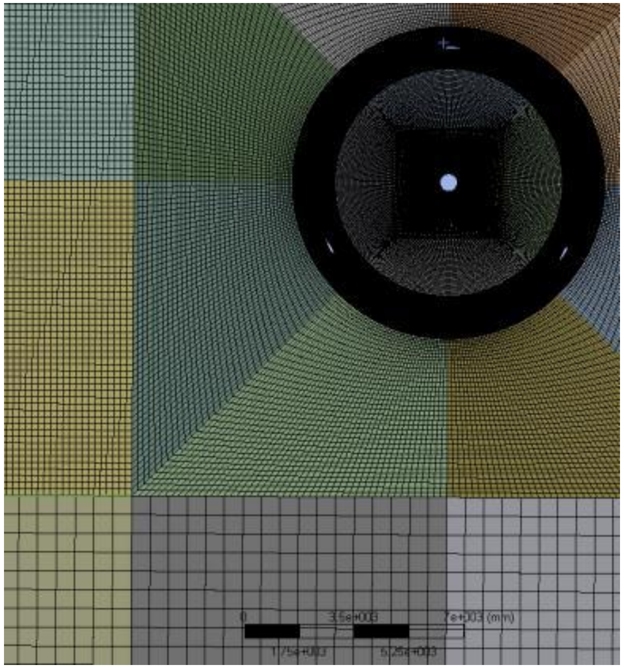


Further parameters:

- Wind turbine diameter
- Aerofoil size ratio
- Wind speed

Modelling





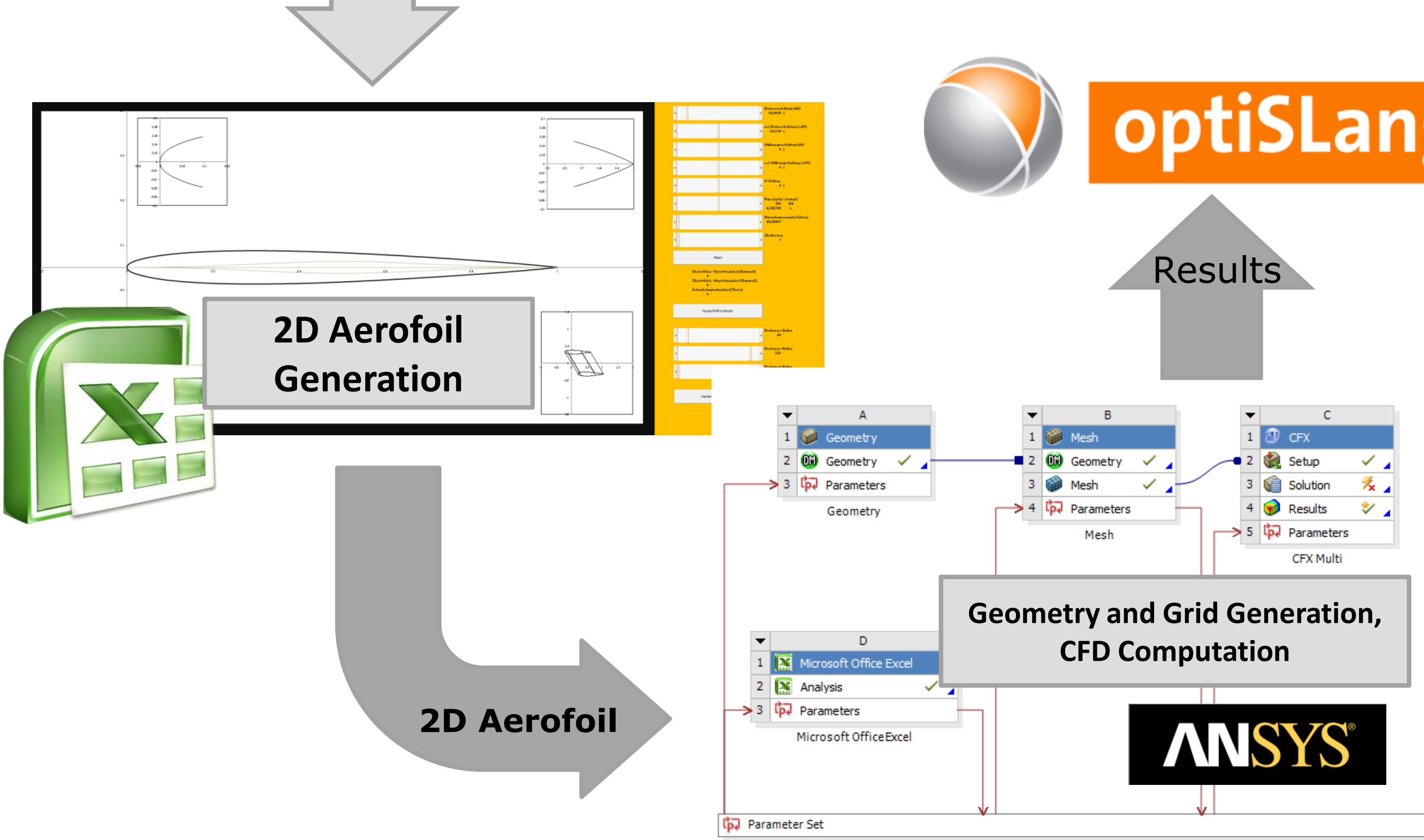
Different geometric scales have to be represented by the grid

→ High grid size

Process

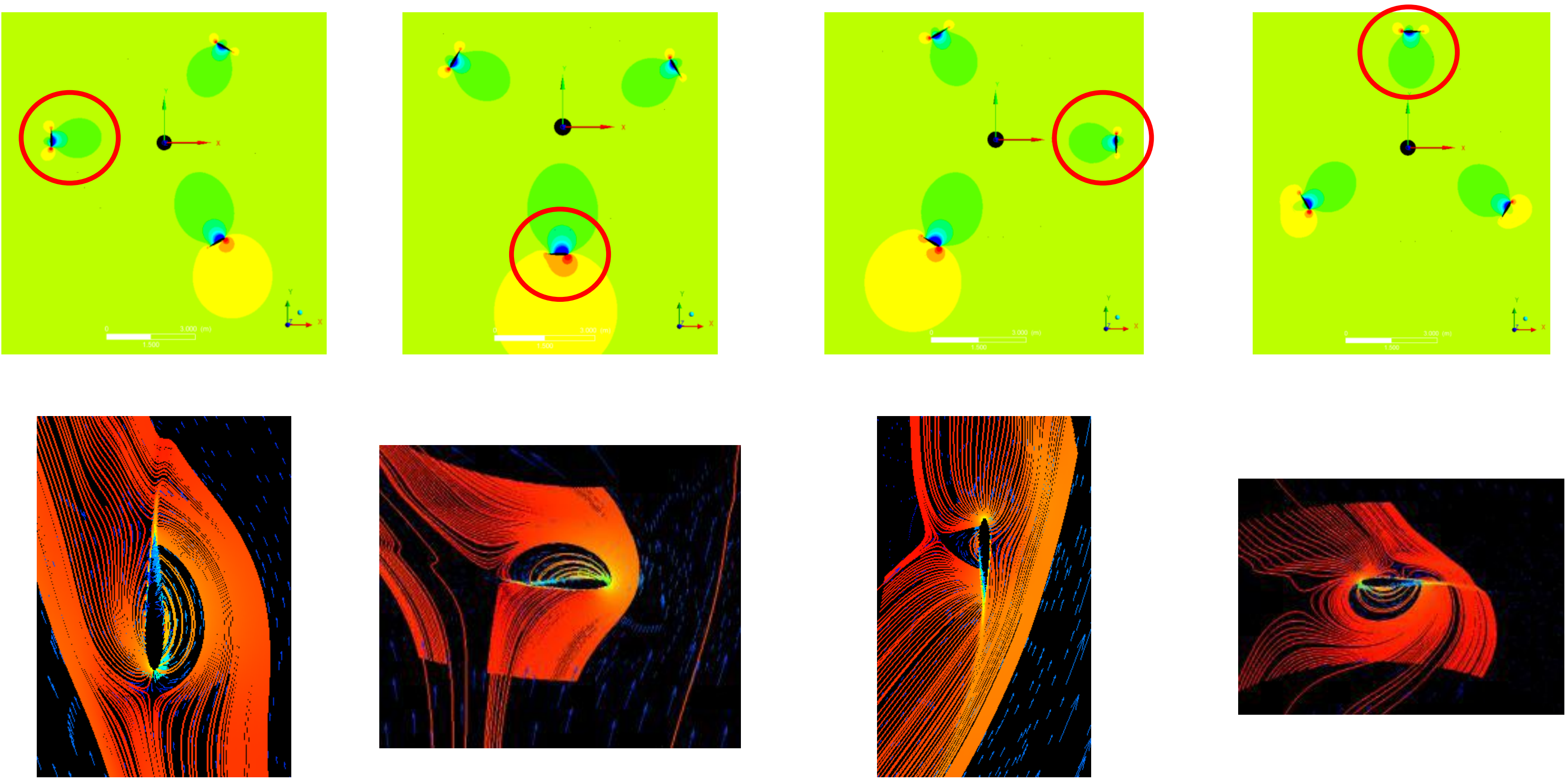
Simulation computationally very expensive: 200 design at 25 workstations running 3 weeks.

Design Parameters



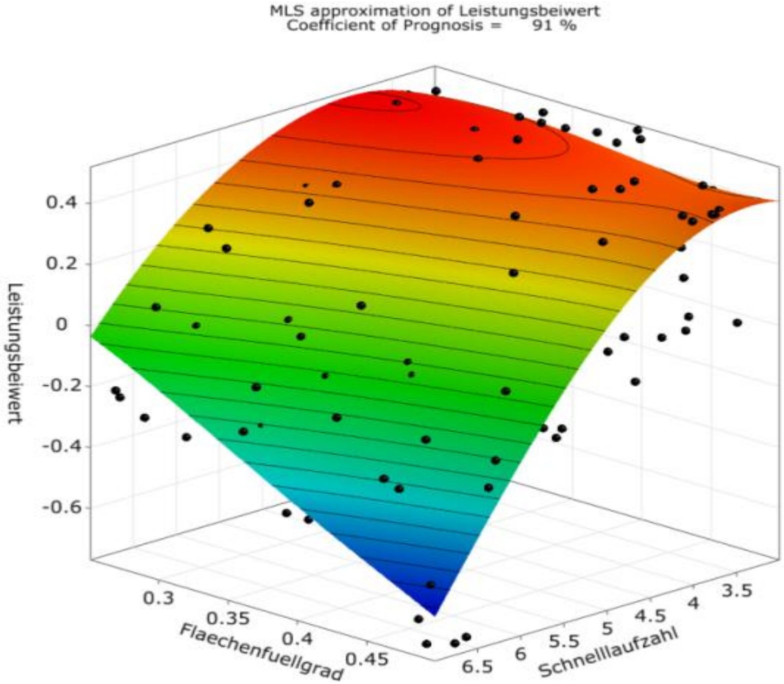
Results

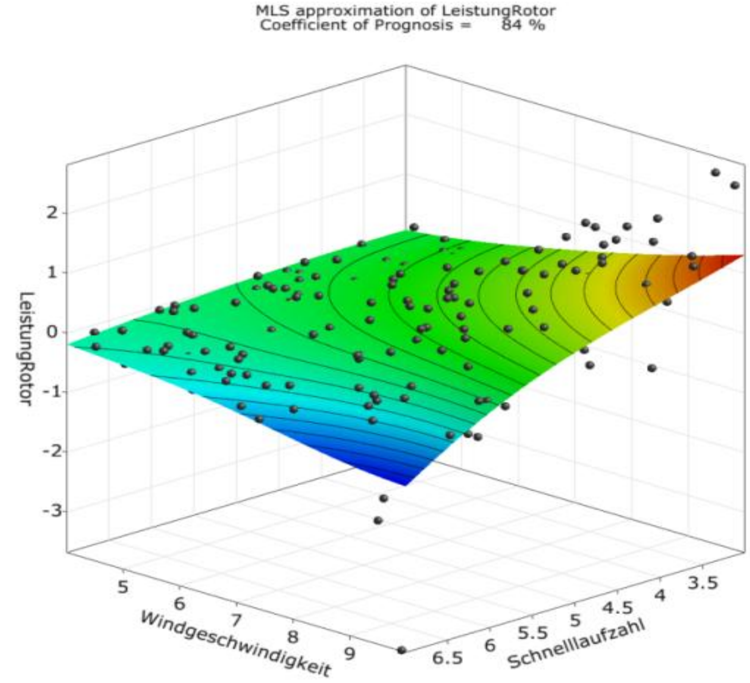
Flow field for one rotor revolution



Results

MLS – Approximation of the Efficiency / Power Output
based on the Meta Model of optimal Prognosis (MoP)



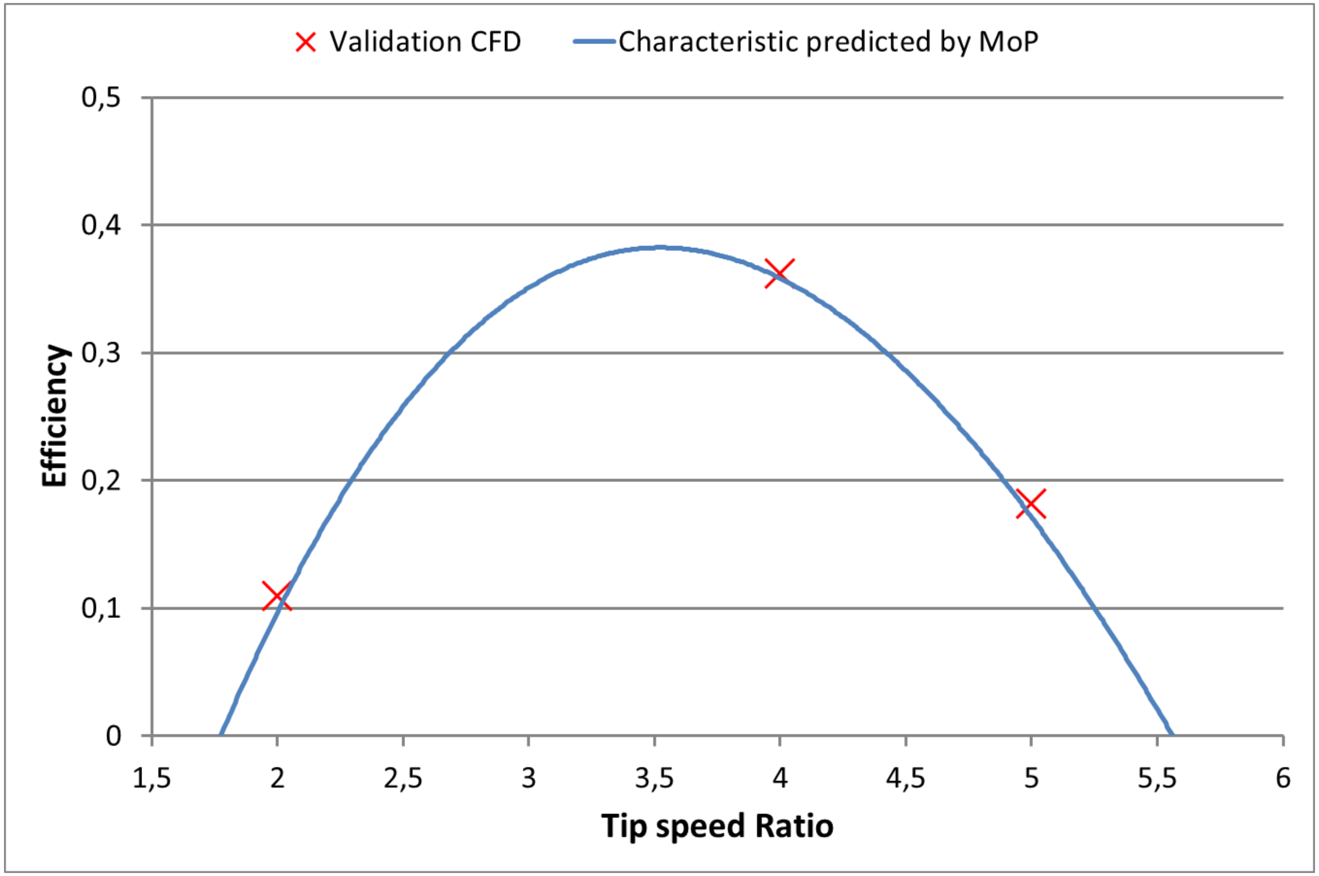


High CoP for both Efficiency and Power Output

(CoP = 91%) (CoP = 84%)

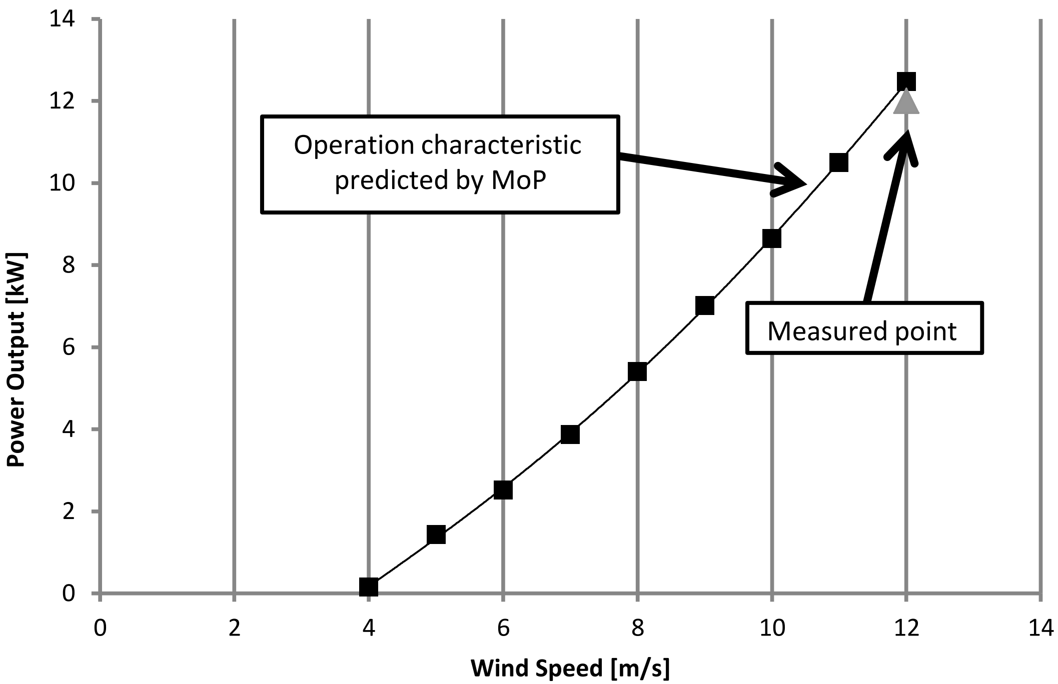
Results

Validation of the metamodel against CFD calculations



Results

Validation of the metamodel against an existing Machine



Marsta-VAWT – University of Uppsala

Summary

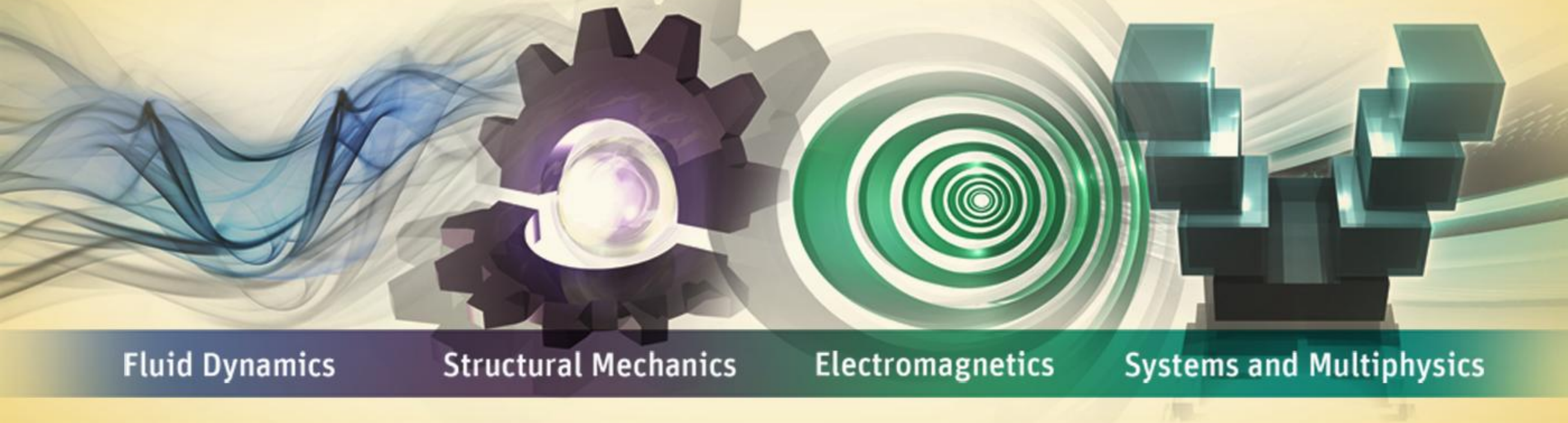
- 200 CFD Designs calculated
- Metamodel with high CoP
- Metamodel validated with additional CFD caluclations
- Metamodel validated against existing machines
- Operation characteristics of arbitrary machines can be predicted natively in optiSLang without further CFD Simulations!

ANSYS

Realize Your Product Promise™

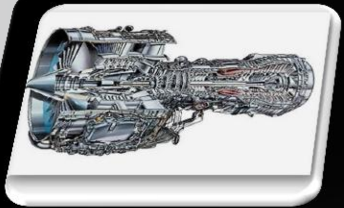
Multi-Physics Design Optimization of an Axial Compressor

Application and Best-Practice Guide-Lines

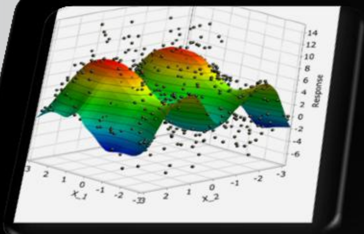


Johannes Einzinger, ANSYS

Overview



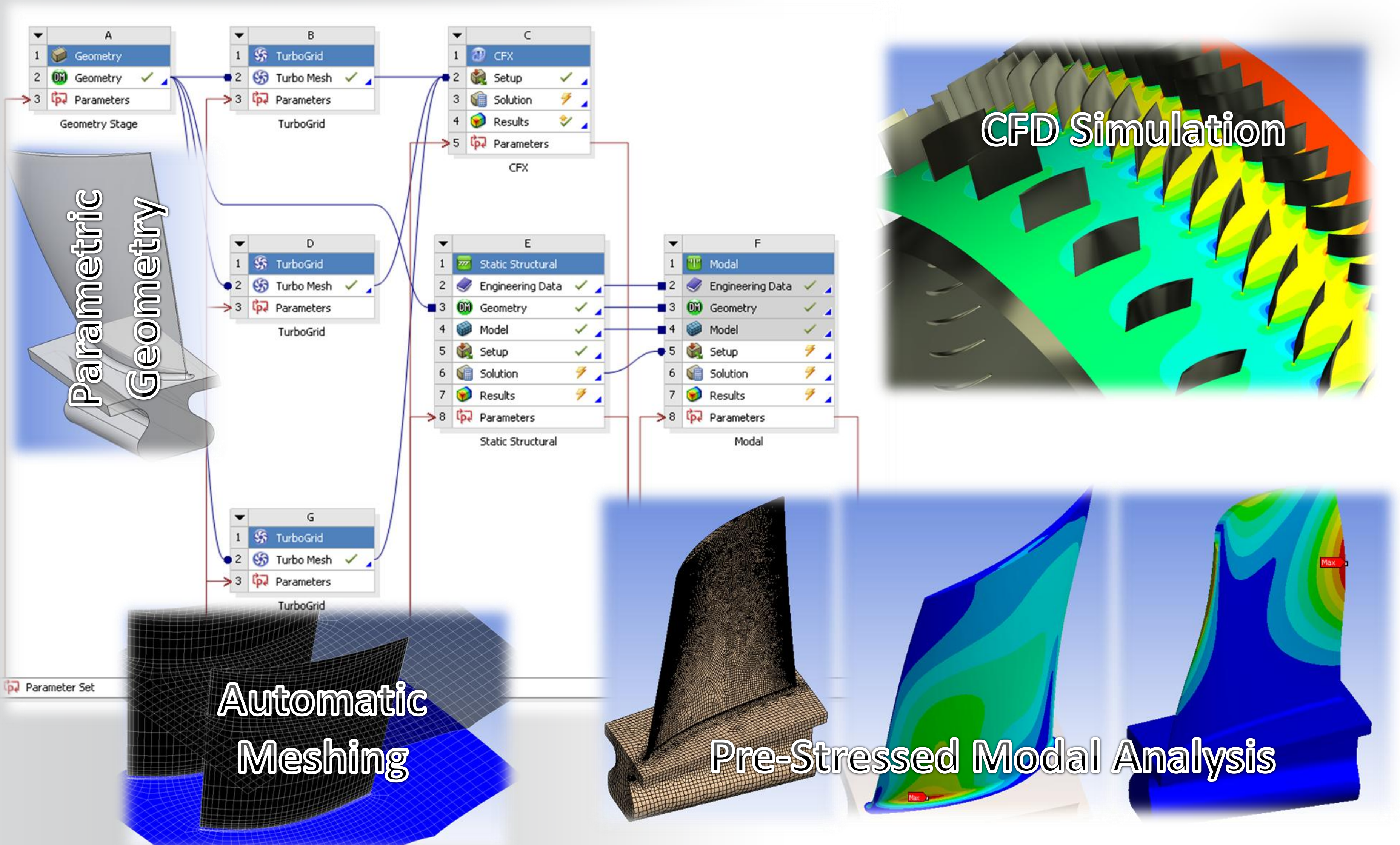
Simulation Model, Best-Practice CFD and FEM



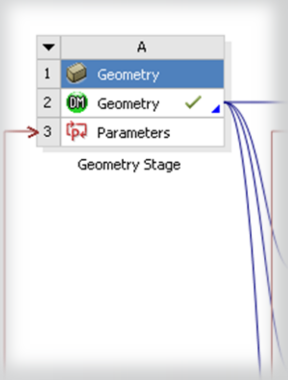
Meta-Model of optimal Prognosis

Best-Practice for MoP

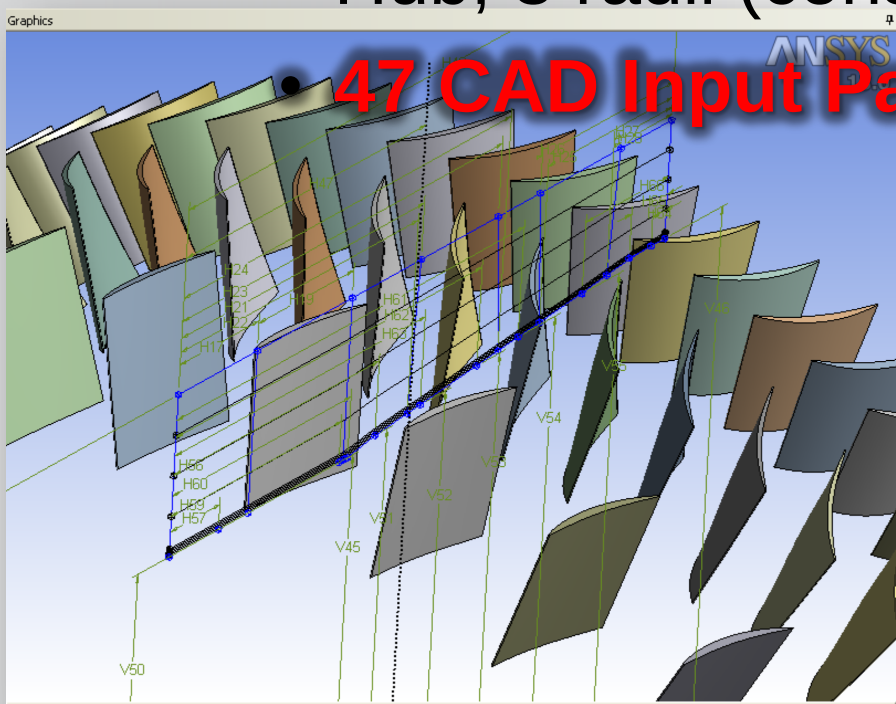
Application Overview

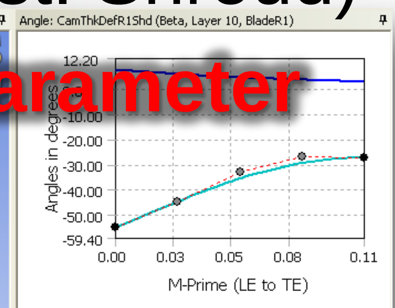


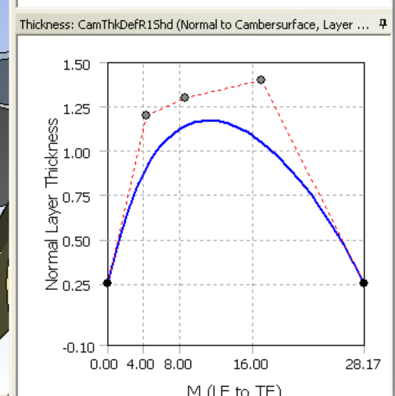
Geometry, Aero Dynamic

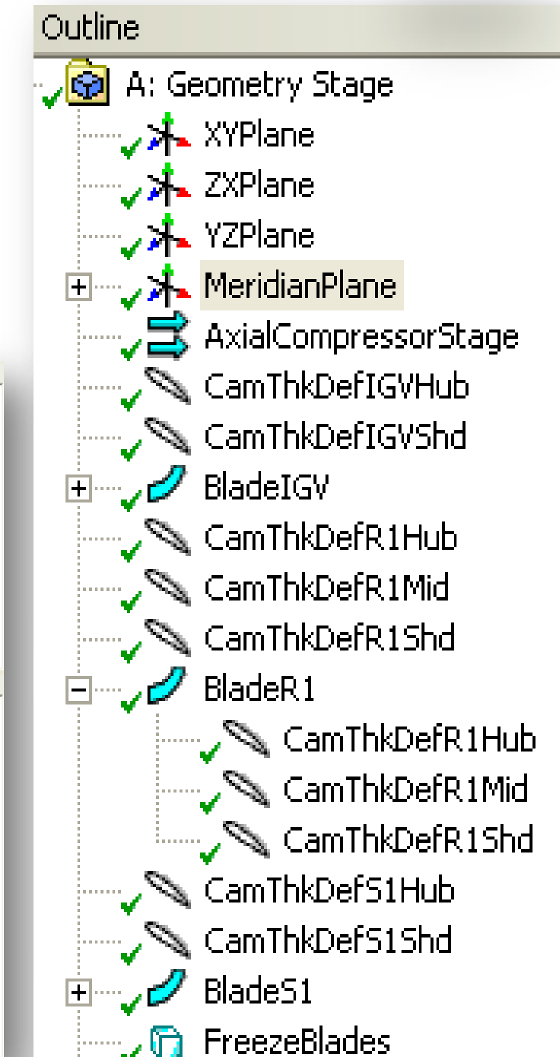


- Camber/Thickness for
  - IGV, R1, S1; 2-3 Layers
  - 5 β_i per Layer, 3xThk
- Hub, 8 radii (const. Shroud)
- **47 CAD Input Parameter**

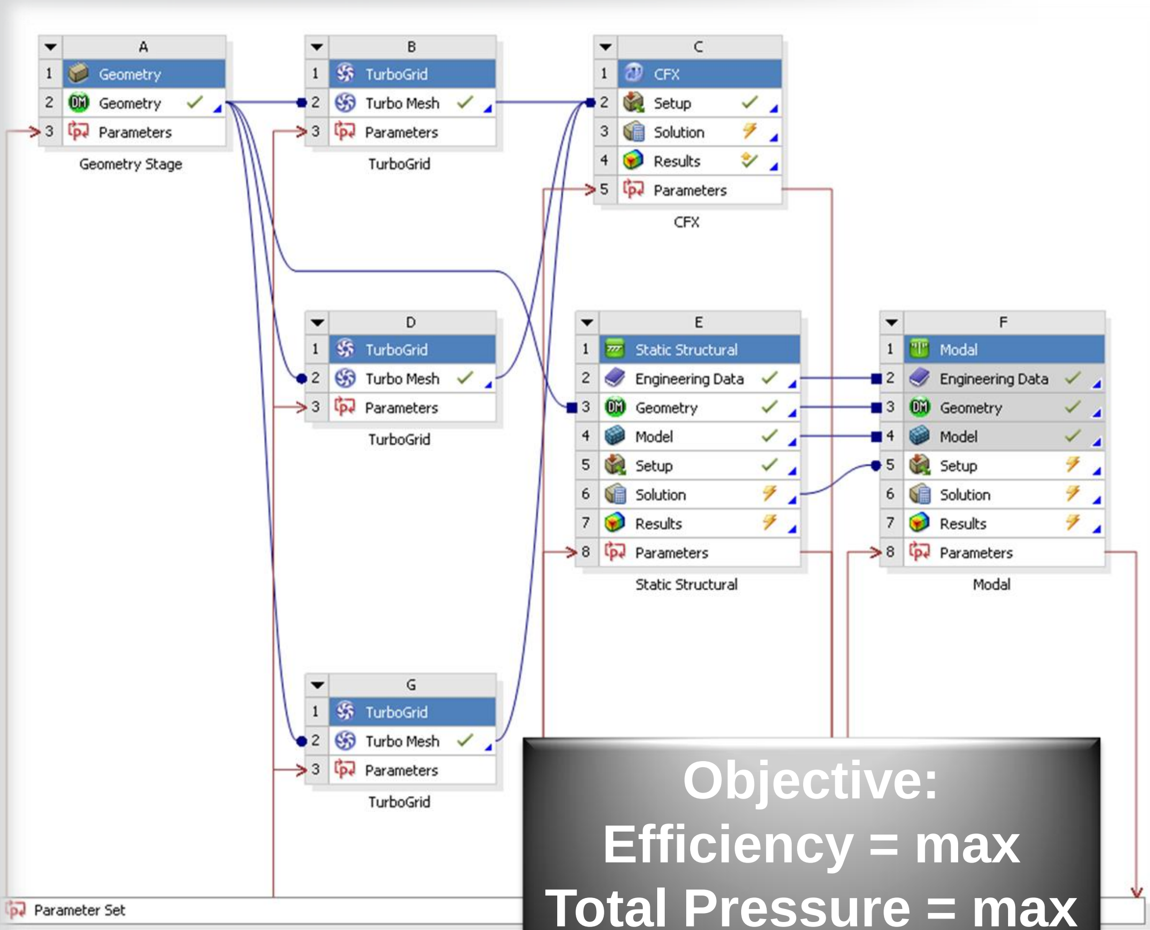








Process and Objectives



Objective:
Efficiency = max
Total Pressure = max
Stress < Limit
No Resonance

Input Parameters	
Geometry Stage (A1)	
TurboGrid (B1)	
TurboGrid (D1)	
TurboGrid (G1)	
CFX (C1)	
P16	nPitchS1
P15	nPitchR1
P14	nPitchIGV
P17	myAirCP
P18	myAirR
P19	myomega
P20	mymass
P21	Ttin
P22	ptin
Static Structural (E1)	
P89	Face Sizing Element Size
P90	Mesh Max Size
P91	Mesh Min Size
P92	Mesh Max Face Size
P93	Rotational Velocity Z Component
P94	ViewExpand ARG1
P111	Density
P112	Young's Modulus
P113	Poisson's Ratio
Modal (F1)	
New input parameter	New name
Output Parameters	
Charts	

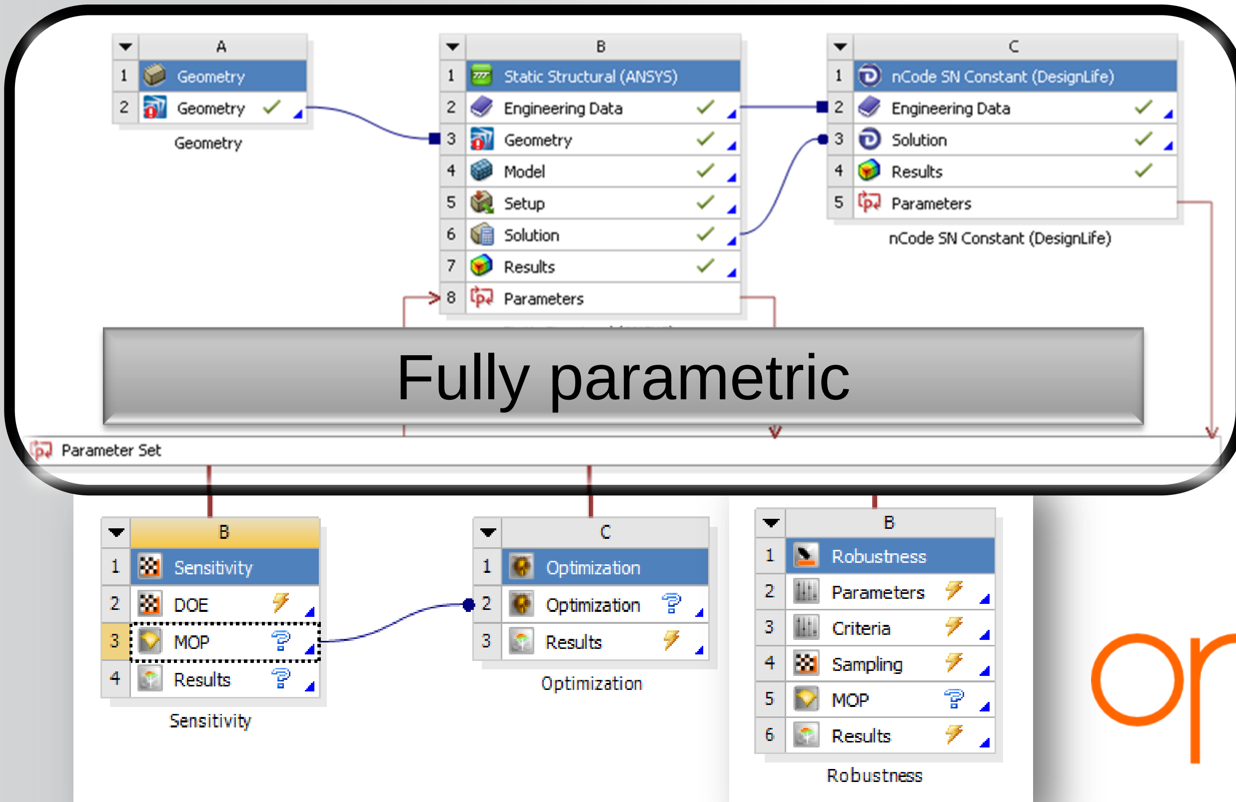
47 (59) Input Parameter

11 Input Constraints

24 Output Parameter

optiSLang inside Workbench

The Workbench Effect – easier to use



Fully parametric

Easy parametric set up of complex simulations

optiSLang optimizing structural language

easy use of best praxis automated flows inside Workbench

ANSYS

Meta-Model of Optimal Prognosis, MoP

Significance Filer

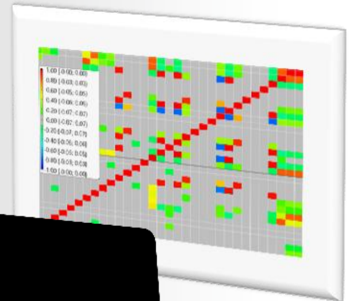
Importance Filter

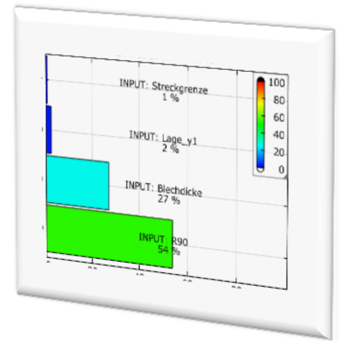
Test-Data Point Split

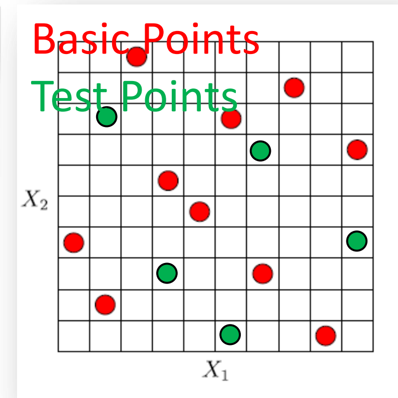
Response Surface

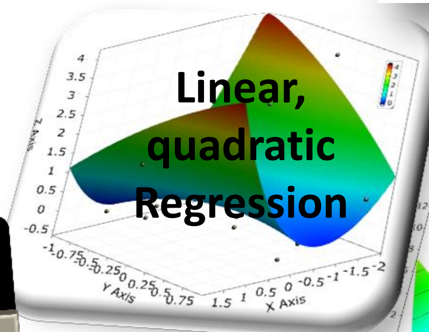
Coefficient of Prognosis

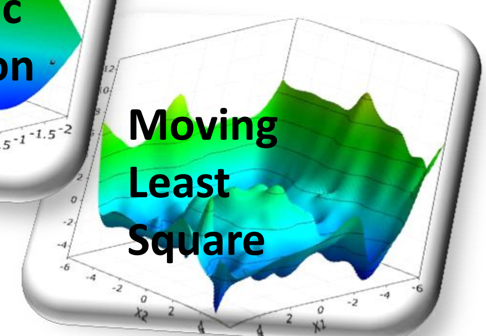
Variation of Filter Limits…





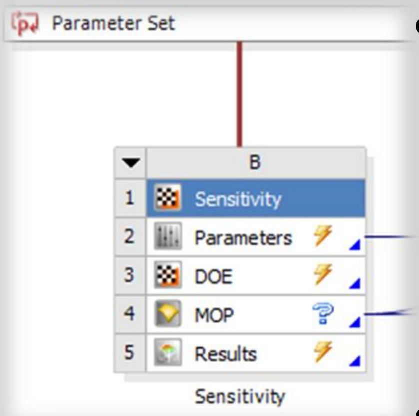




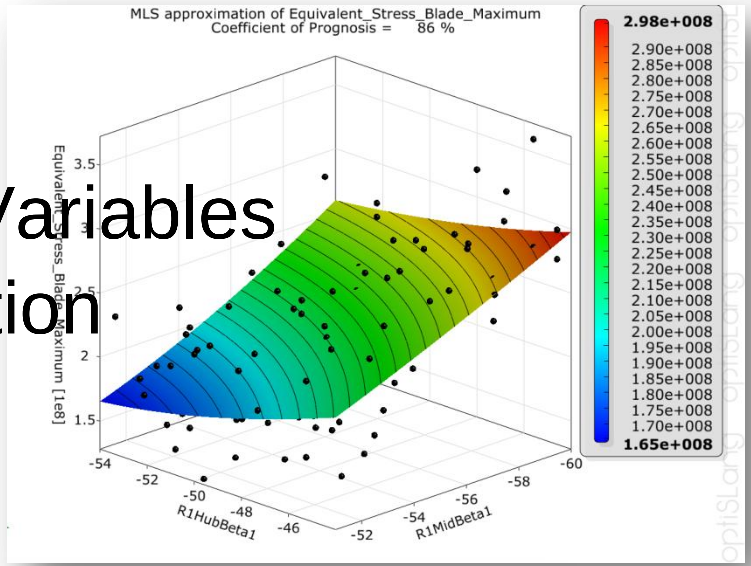


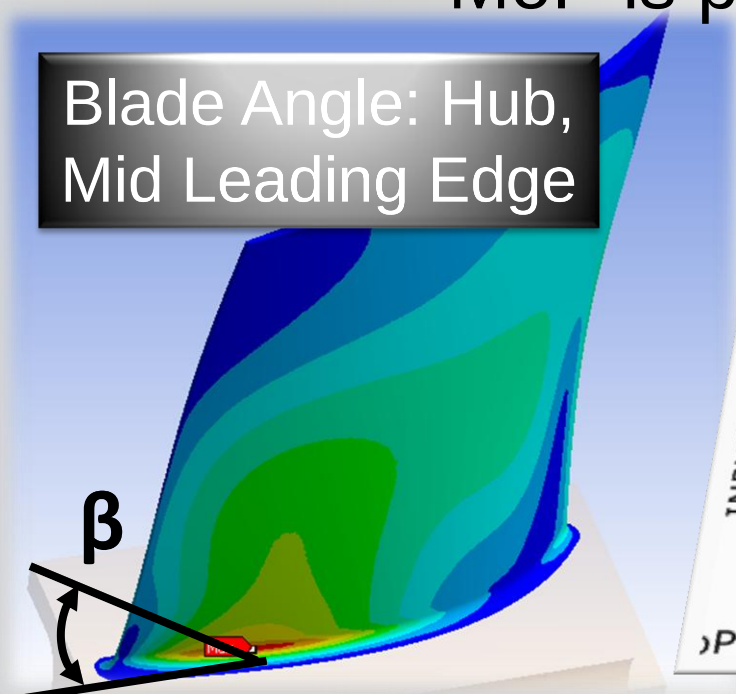
$$CoP = \left(\frac{E\left(Y \cdot \hat{Y}\right)}{\sigma_Y \cdot \sigma_{\hat{Y}}} \right)^2 = \left(\frac{\sum_{k=1}^{N} \left(y^{(k)} - \mu_y\right) \cdot \left(\hat{y}^{(k)} - \mu_{\hat{y}}\right)}{\left(N-1\right) \cdot \sigma_Y \cdot \sigma_{\hat{Y}}} \right)^2$$

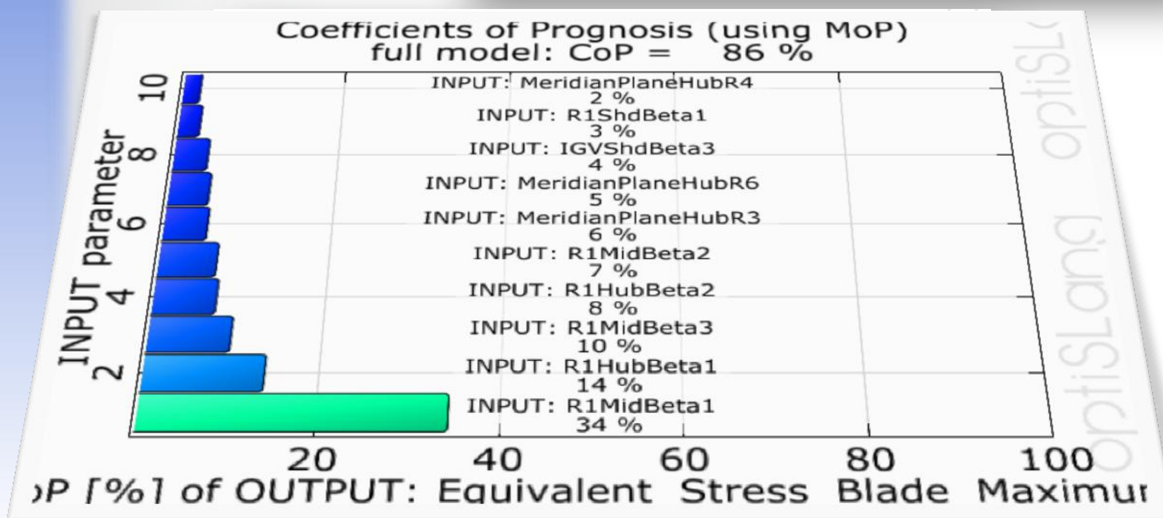
Maximal Stress



- CoP=86%
  - Statistic is reliable
  - Detect important Variables
  - Parameter Reduction
- MoP is plausible

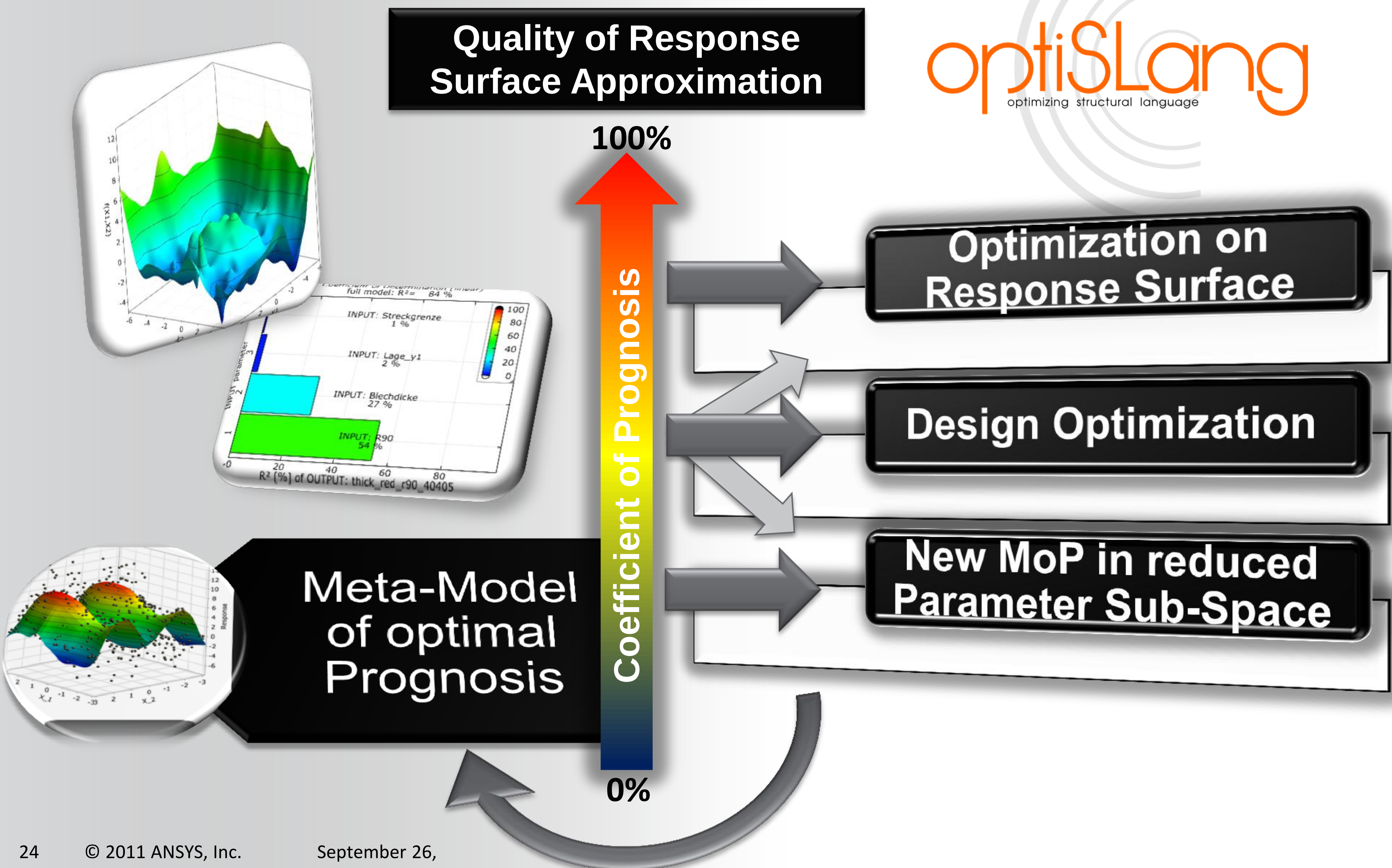




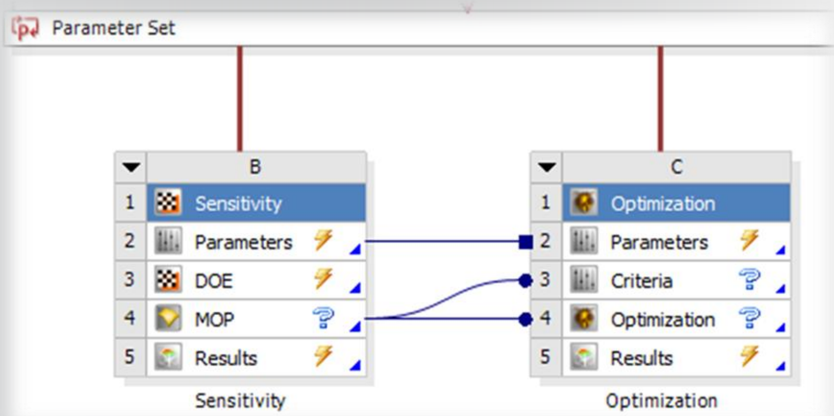


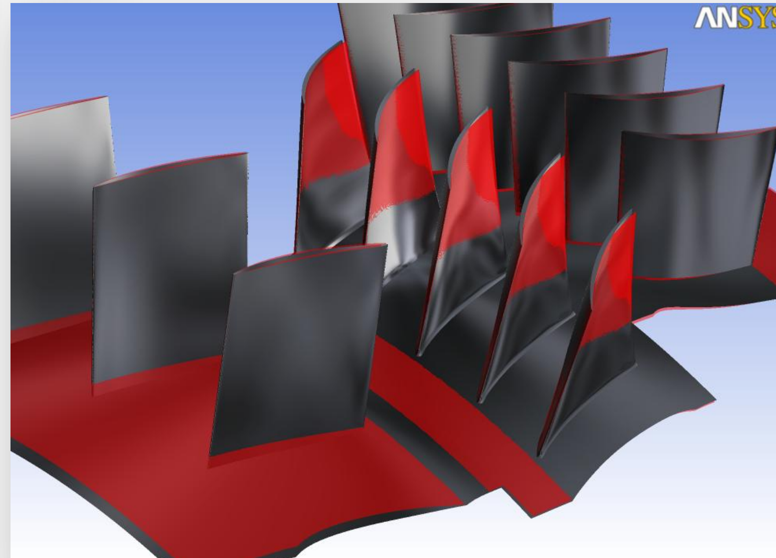
ANSYS

optiSLang Strategy



Design Optimization, Summary





	Initial Design	Best Design SA	Best Design Solved (MoP)	Best Design ARSM
Efficiency [%]	87.0	88.0	88.9 (91.0)	88.9
p_{tot} Ratio [-]	1.41	1.41	1.41 (1.44)	1.41
Max. Stress [MPa]	219	235	232 (230)	239
#Designs	1	150	1 (0)	100

