# Probabilistische CFD–Simulation einer Hochdruckverdichterstufe unter Berücksichtigung von Fertigungstoleranzen

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Henner Schrapp, Erik Johann, Volker Gümmer (RRD)

Dresden, 9. Oktober 2009
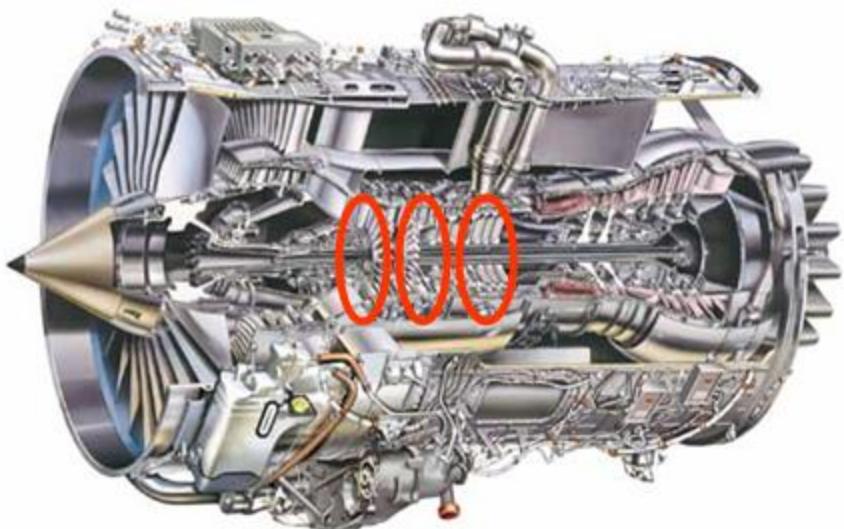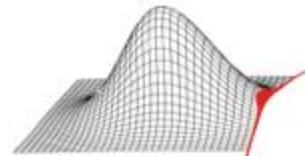
target:
influence of manufacturing
tolerances on properties of
compressor

↓

measurement of HPC blades to
obtain geometric variations

↓

probabilistic
CFD simulations

↓

compressor characteristics with scatter

Overview
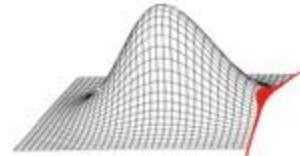
- Introduction

- **Parameter model**

- Statistical Analysis

- Probabilistic Simulation
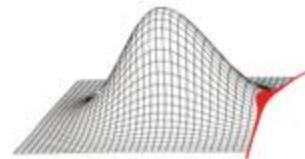
Way from measured data to parameters

1. sorting of discrete points into slices (spanwise constant)
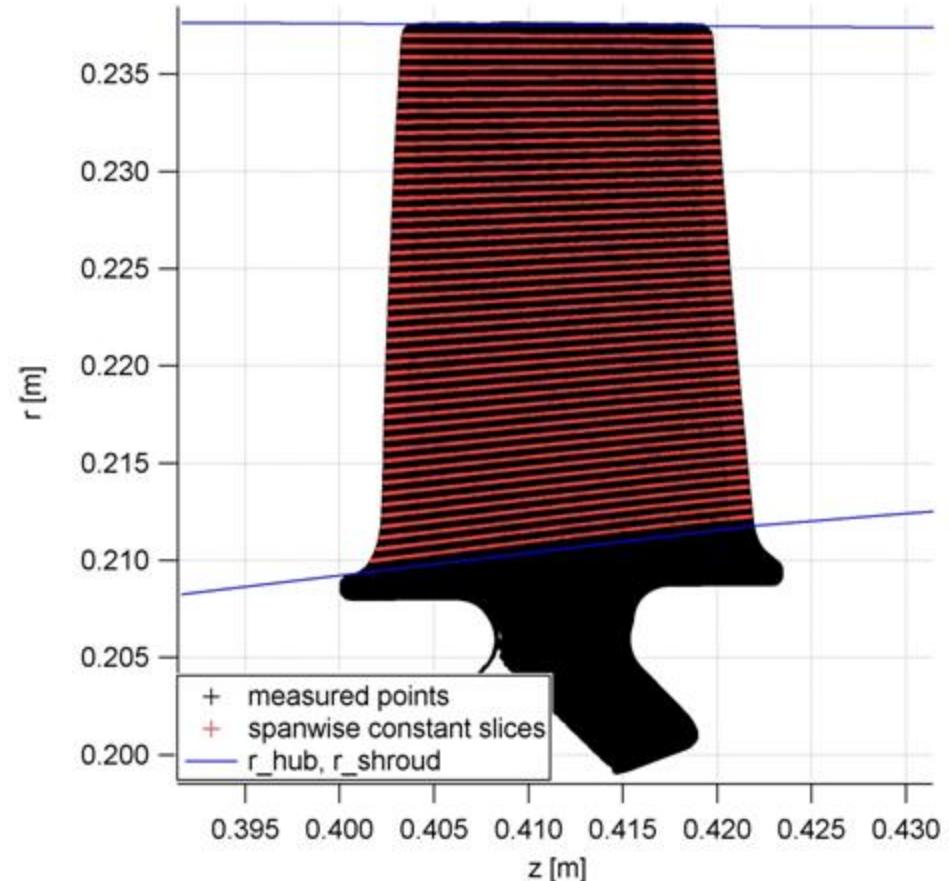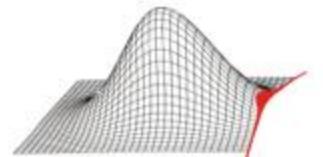
Way from measured data to parameters

1. sorting of discrete points into slices (spanwise constant)

2. section outline trough rotation symmetric face

3. calculation of camber line and chord line
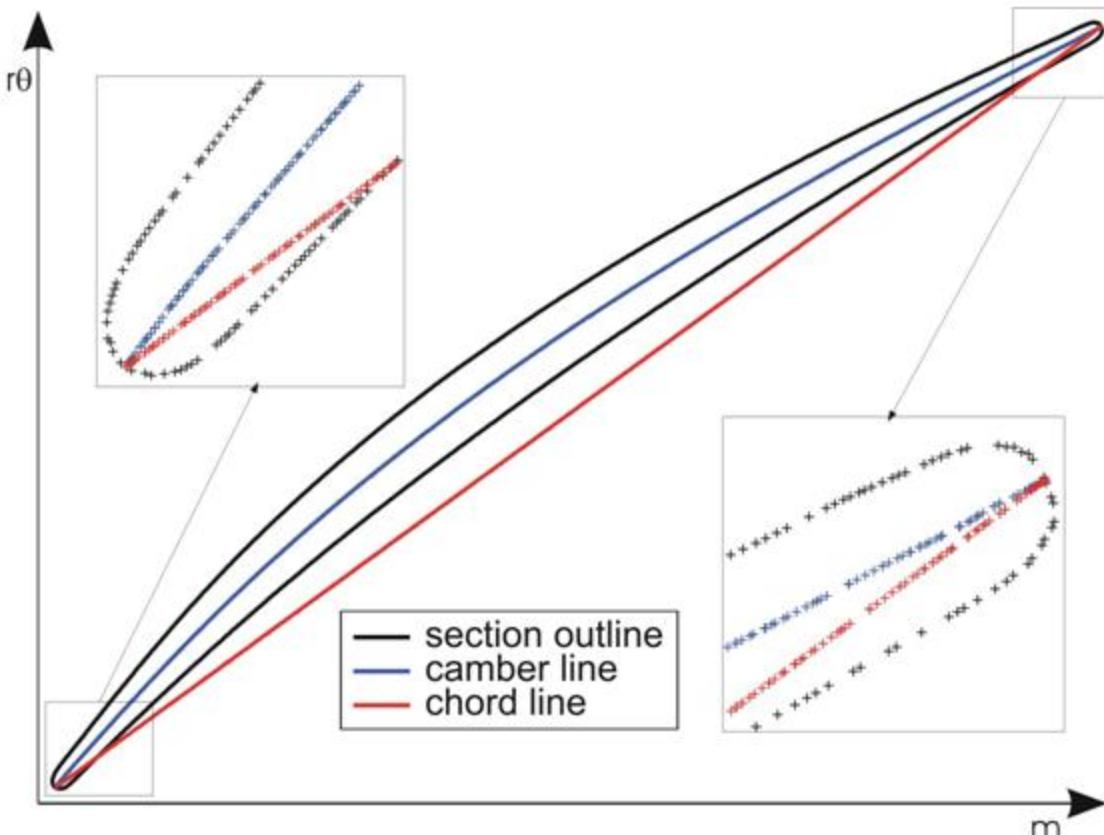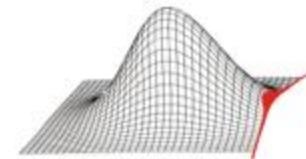
## Way from measured data to parameters

1. sorting of discrete points into slices (spanwise constant)

2. section outline trough rotation symmetric face

3. calculation of camber line and chord line

4. calculation of camber and thickness distribution
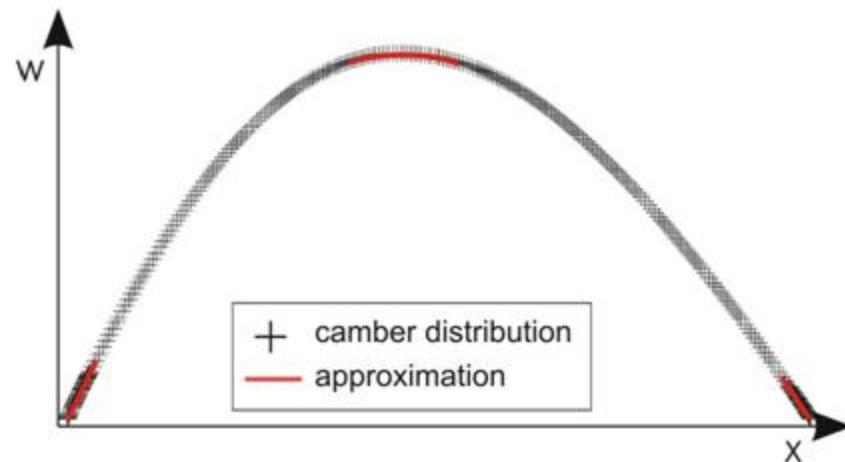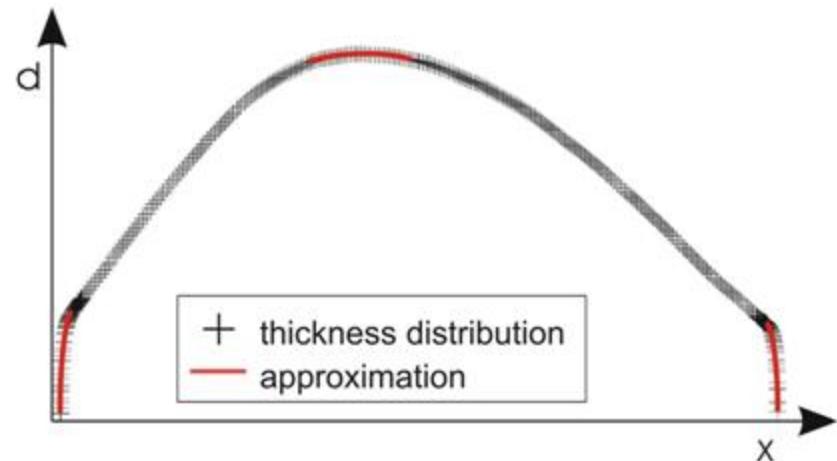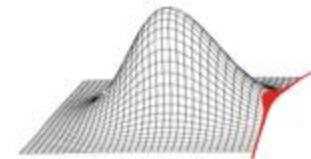
## Parameter model – number of parameters for blade

parameters/section (14) * no of sections + parameters for fillet (2)

Overview
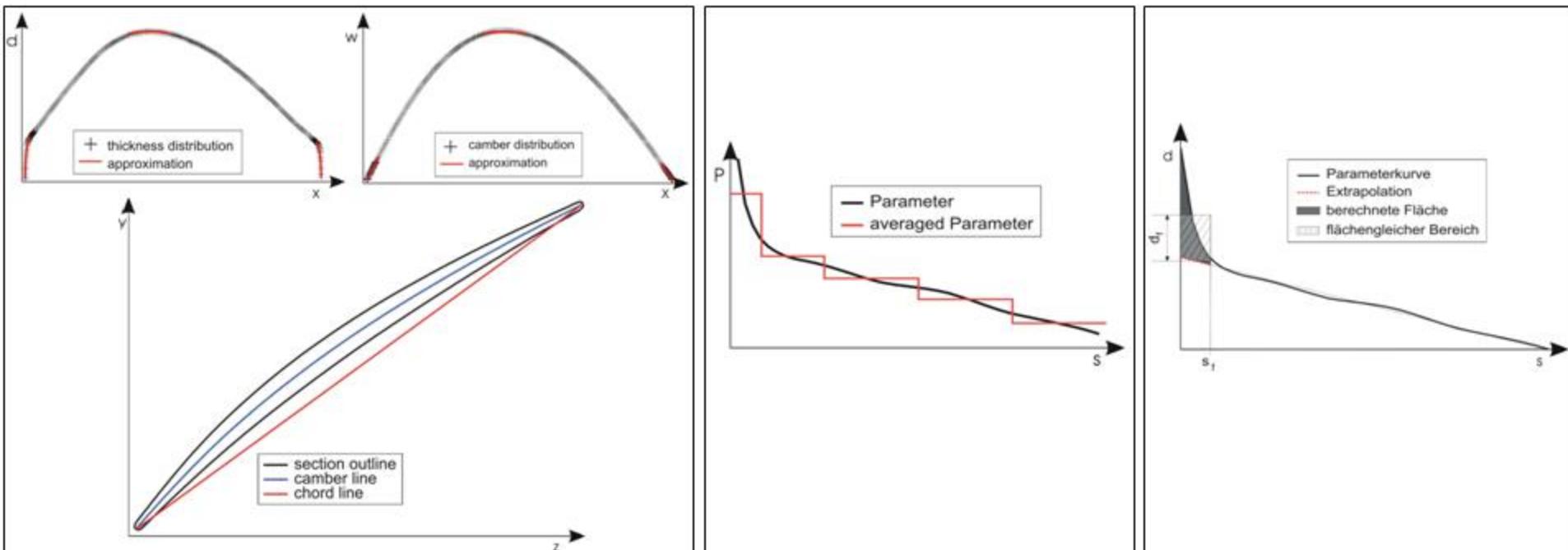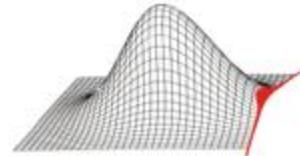
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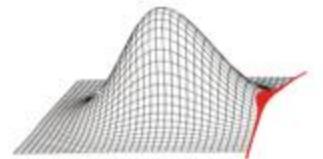
Parameter vs. spanwise coordinate
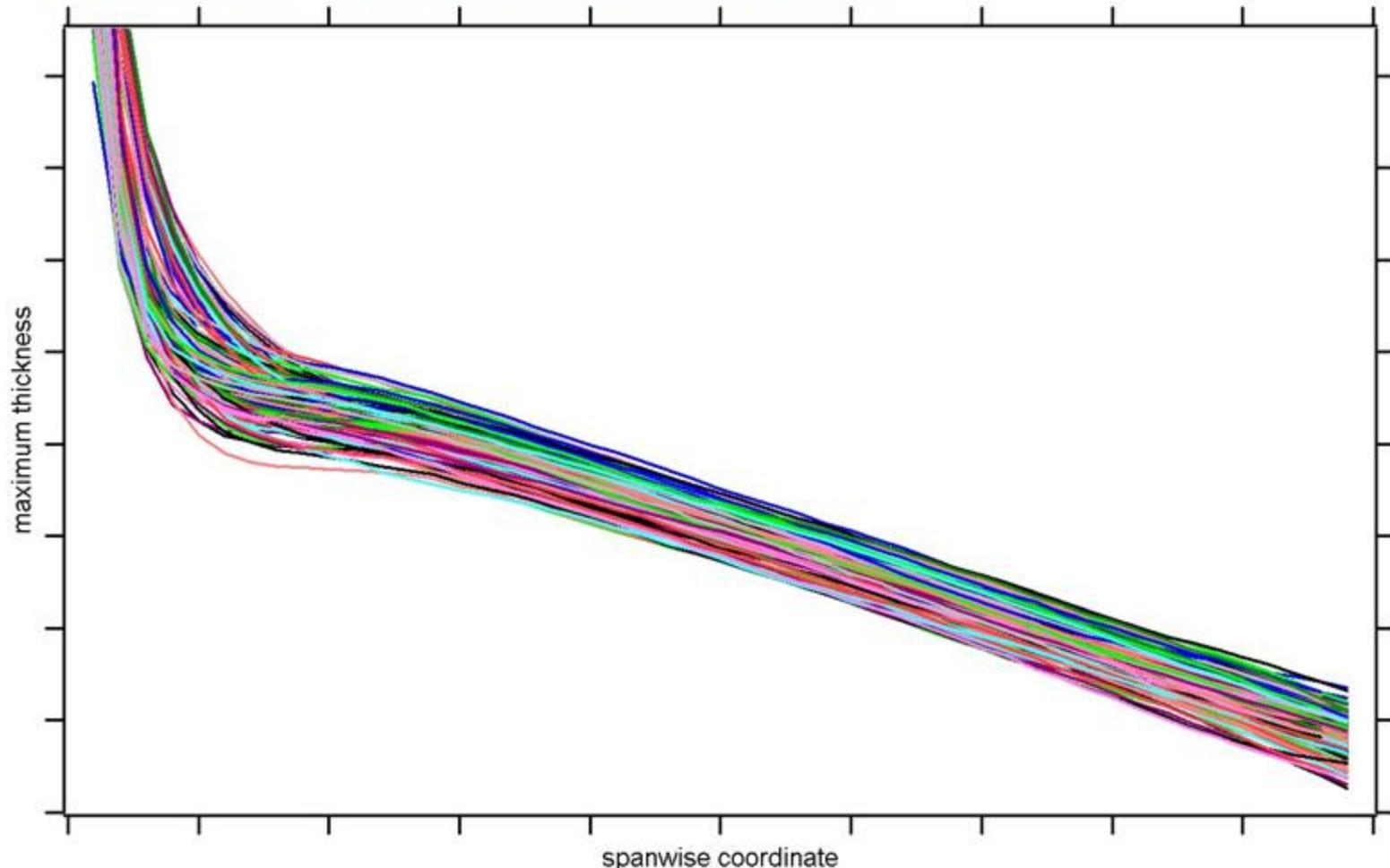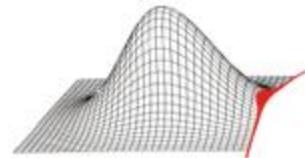
Correlation between input parameters (10 sections)
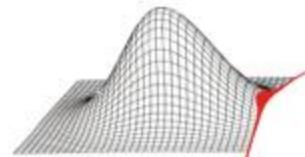
Correlation between input parameters (10 sections)
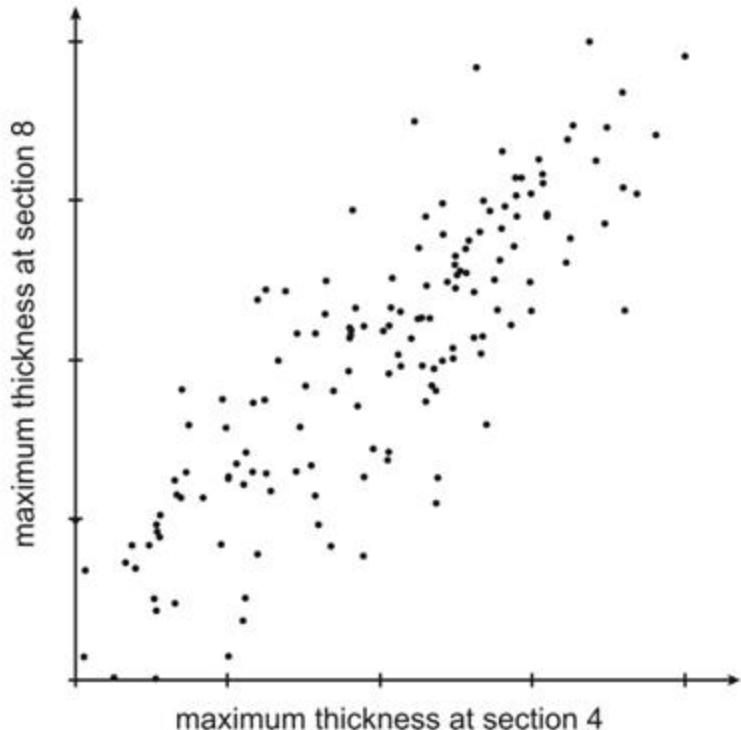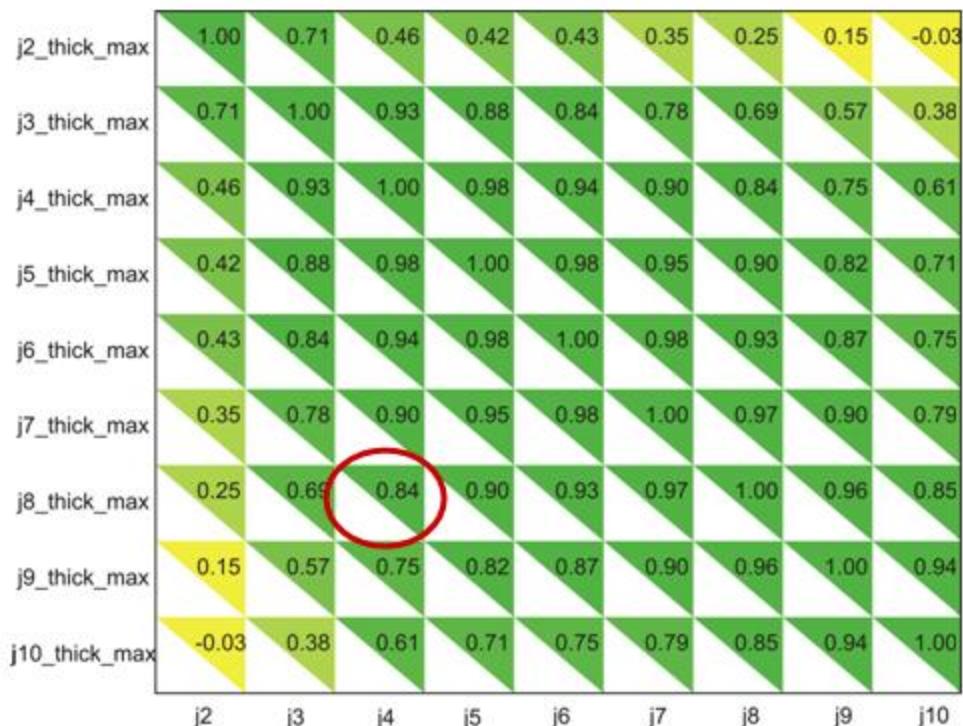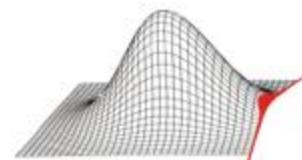
How many averaged sections are needed?

- calculation of scanned blades (no probabilistic methods used)
→ determine required number of spanwise averaged sections (1 vs. 2 vs. 3 vs. 5)
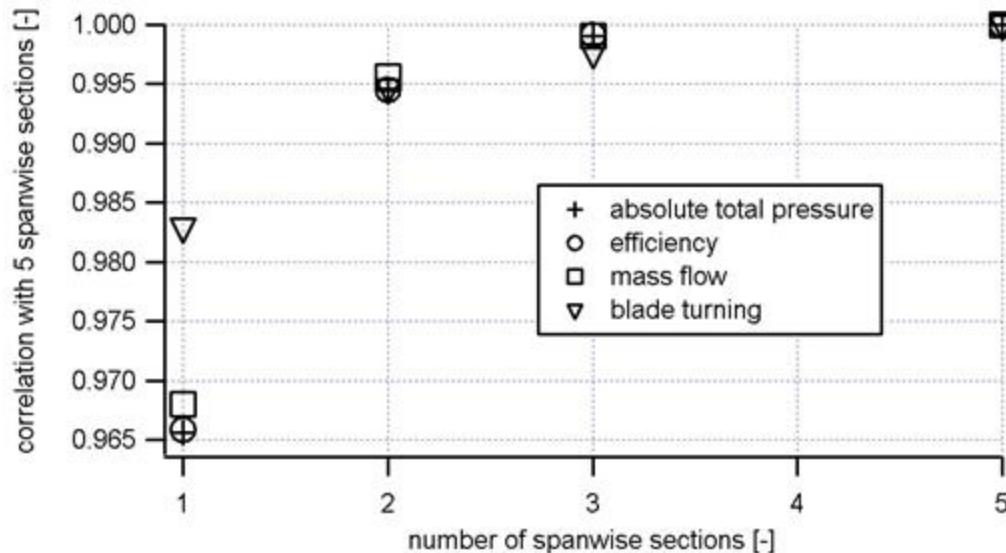
→ 1 spanwise averaged section captures dominating effects
→ advantages in post processing
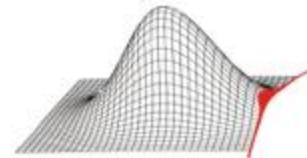
## Correlation between input parameters (1 section)
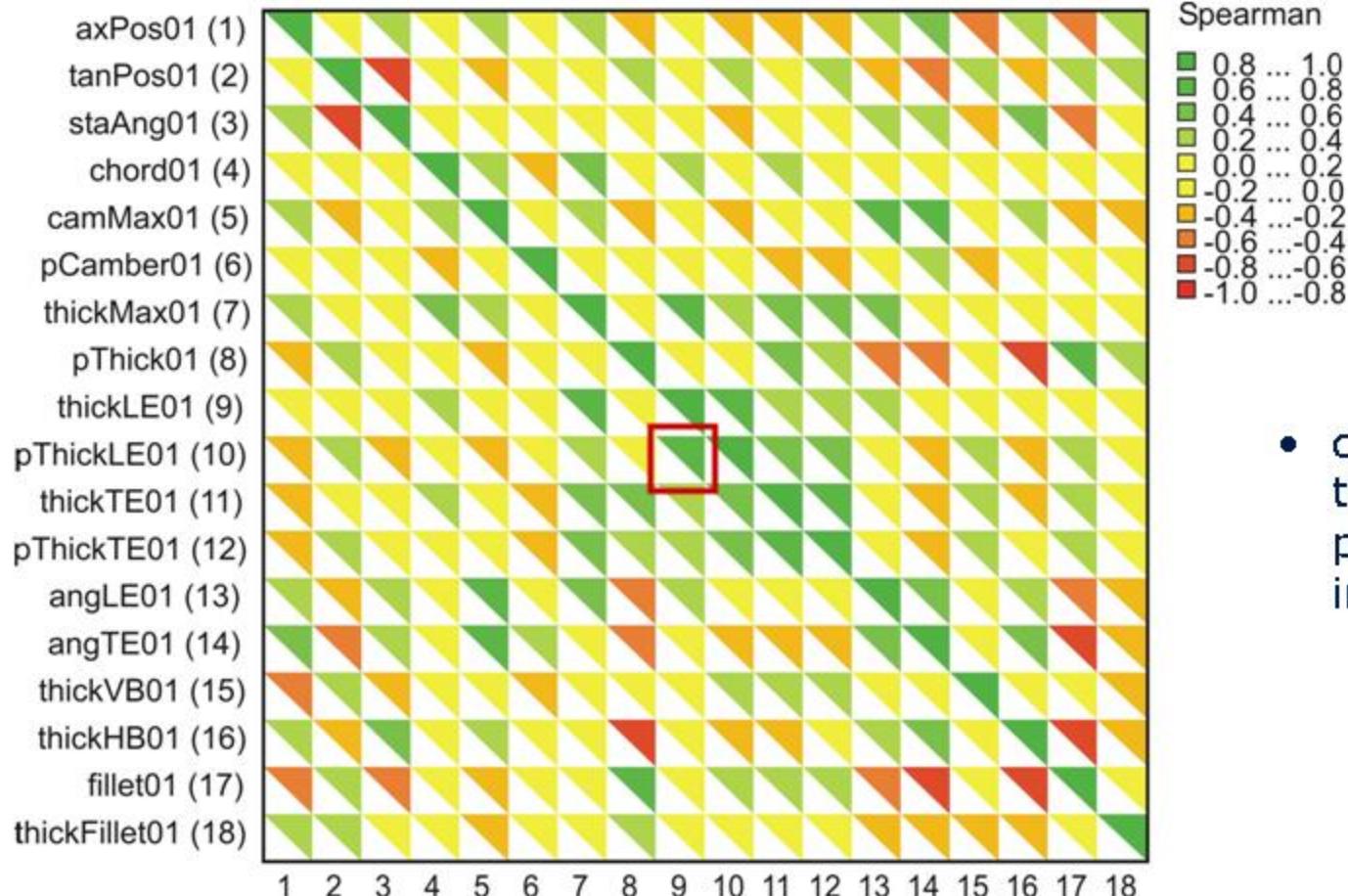
- considered in MCS through restrictive pairing (implemented in ProSi)
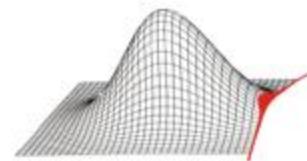
## Ant-Hill-Plot: pos of thickness LE vs. thickness of LE
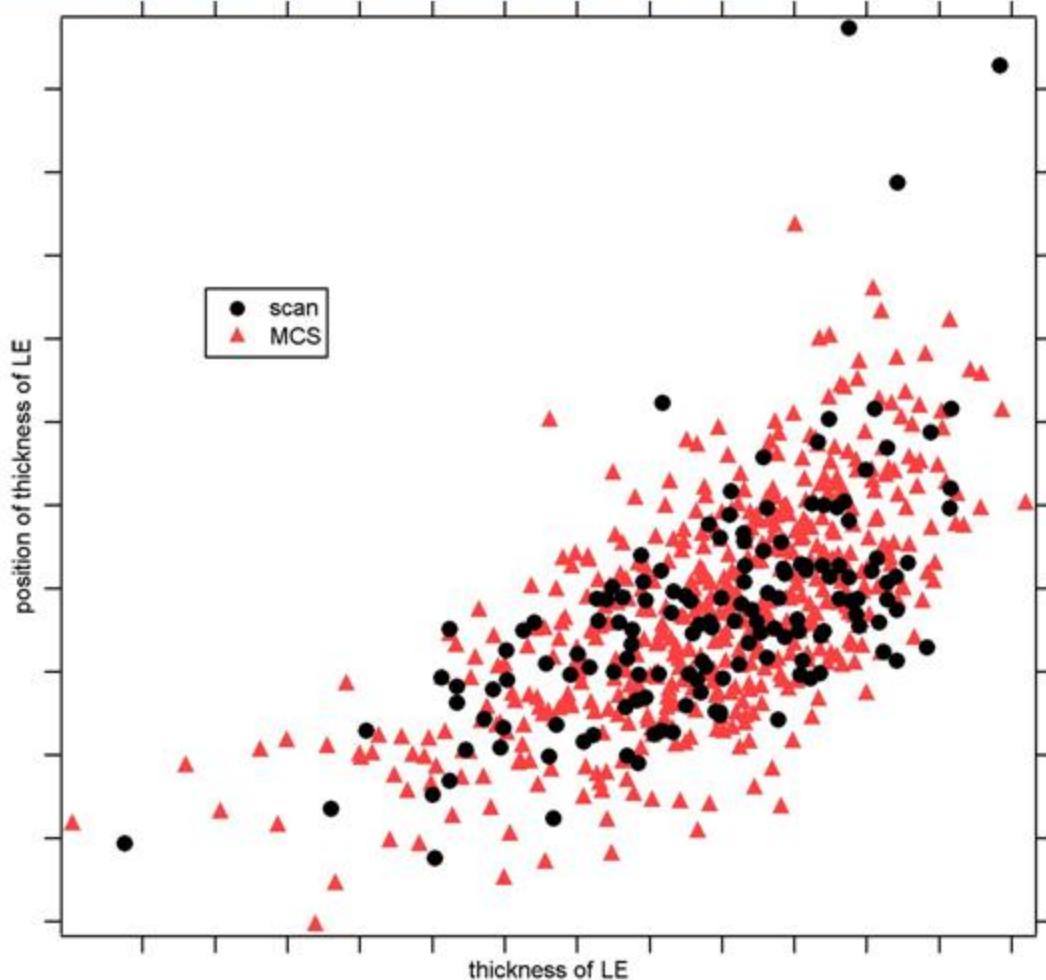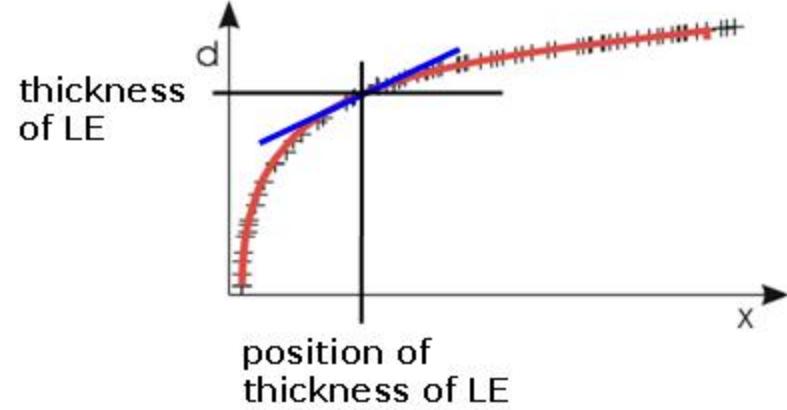
→ correlation of thickness of LE
 with position of thickness of LE

→ tendency to circular shape
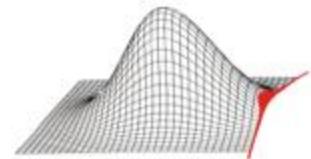
Fitting of determined distributions
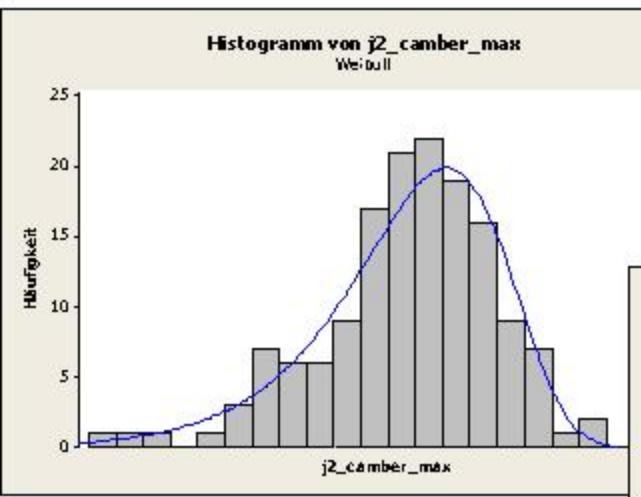
- Minitab
- best distribution through min. AD-value
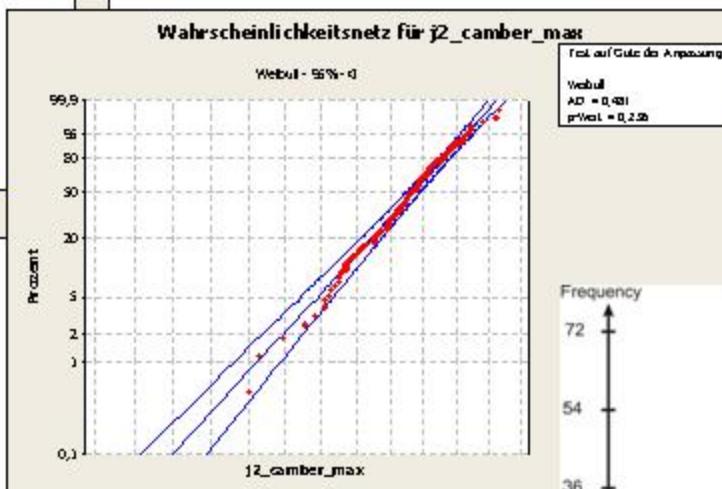
- ProSi
- MCS with 500 shots using LHS
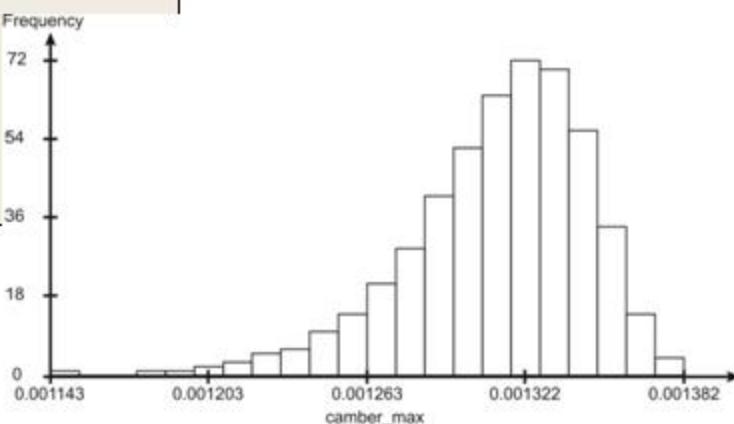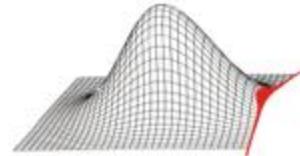
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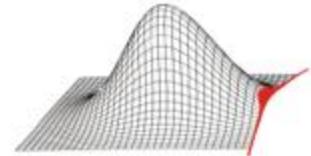
Model

- CFD-Model:
  - 1.5 HPC-stage of BR710
  - ~300k points per blade
  - $pt(r)$, $Tt(r)$ and flow angle at inlet and $ps(r)$ at outlet defined
- Probabilistic Model:
  - Monte Carlo Simulation with 500 shots
  - consideration correlations between parameters
  - 1 spanwise averaged section used → 16 Parameter
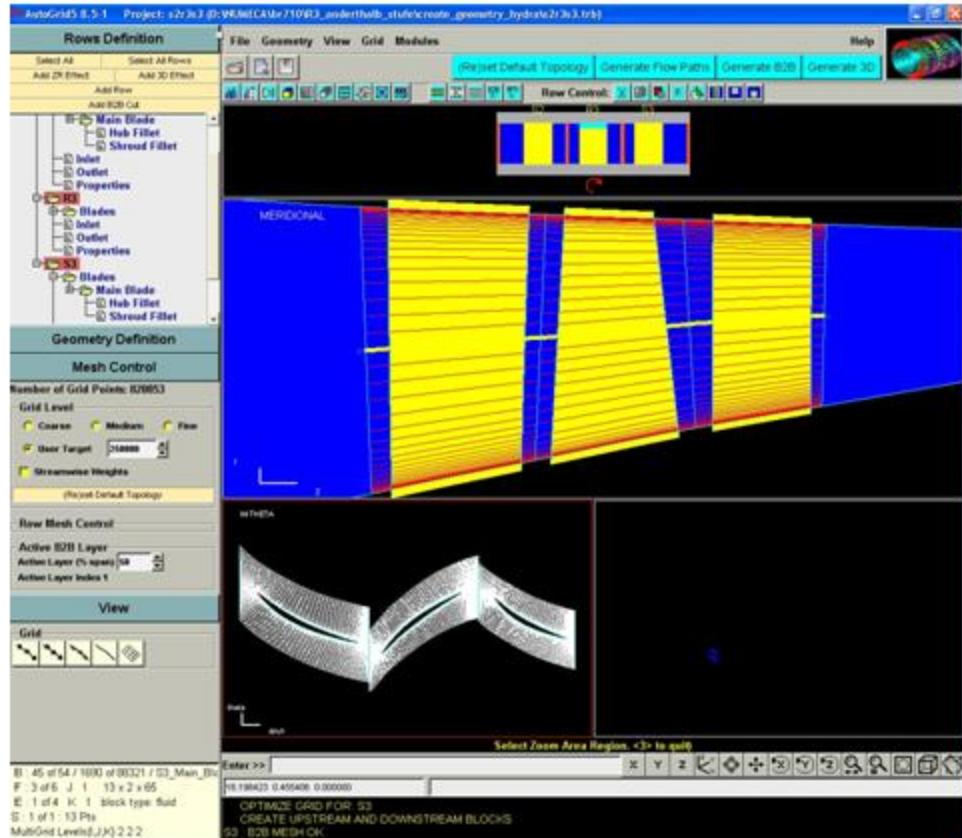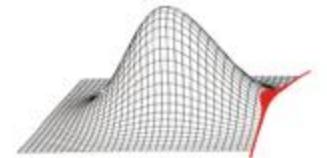
blade surface of 1.5 stage
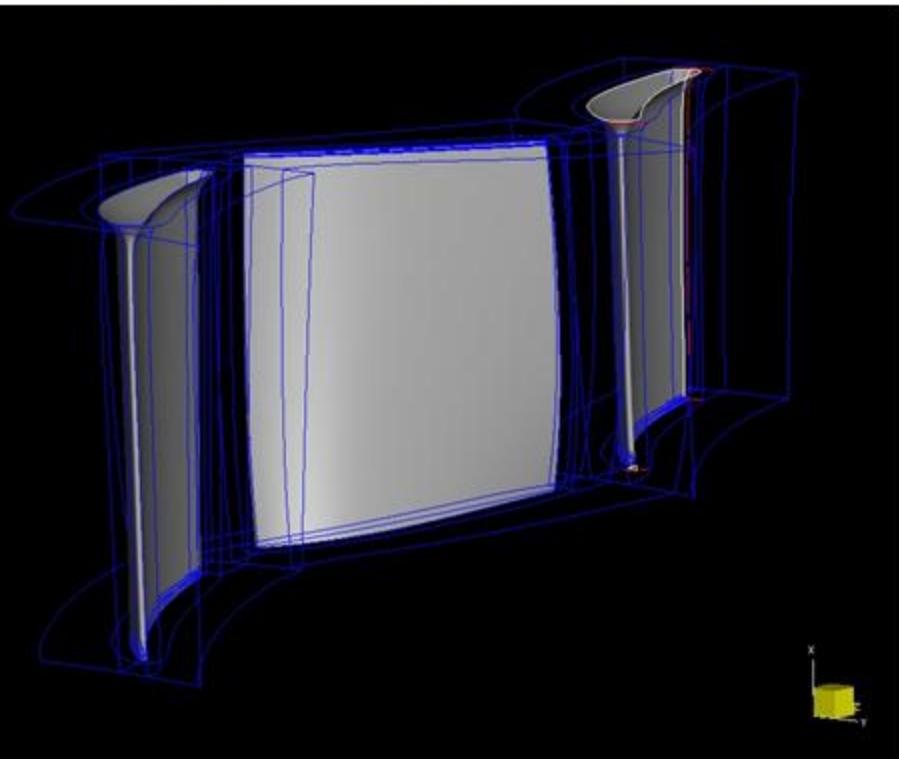
base-mesh
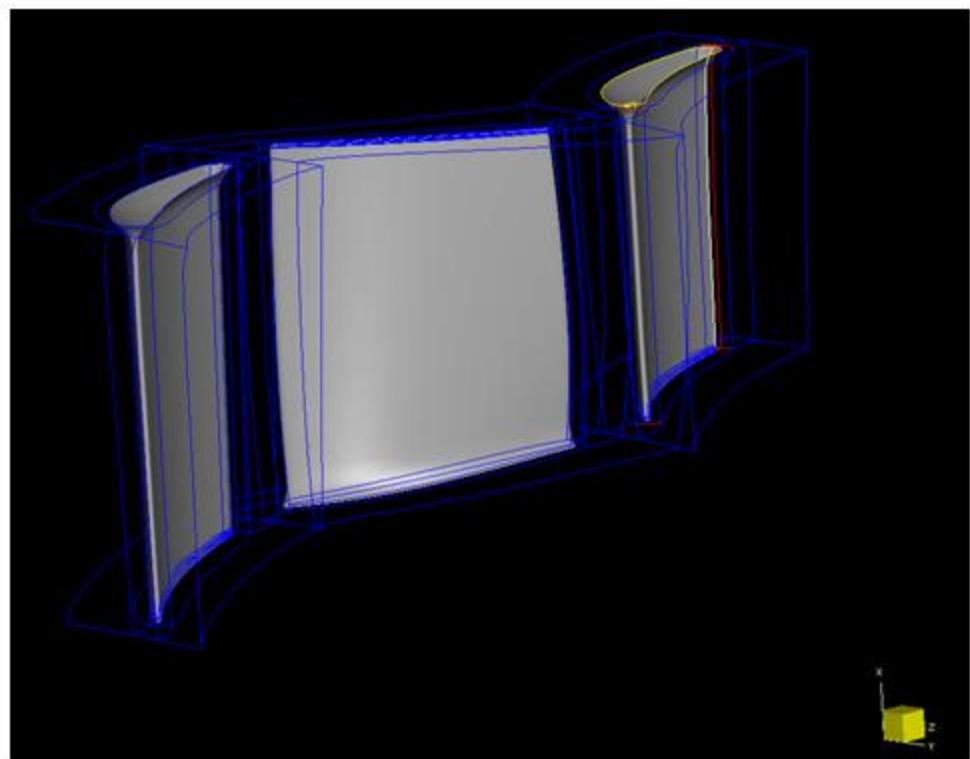
realization
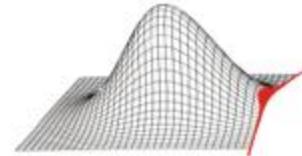
Mesh-Morphing

- share the deformation between O-grid and H-grids
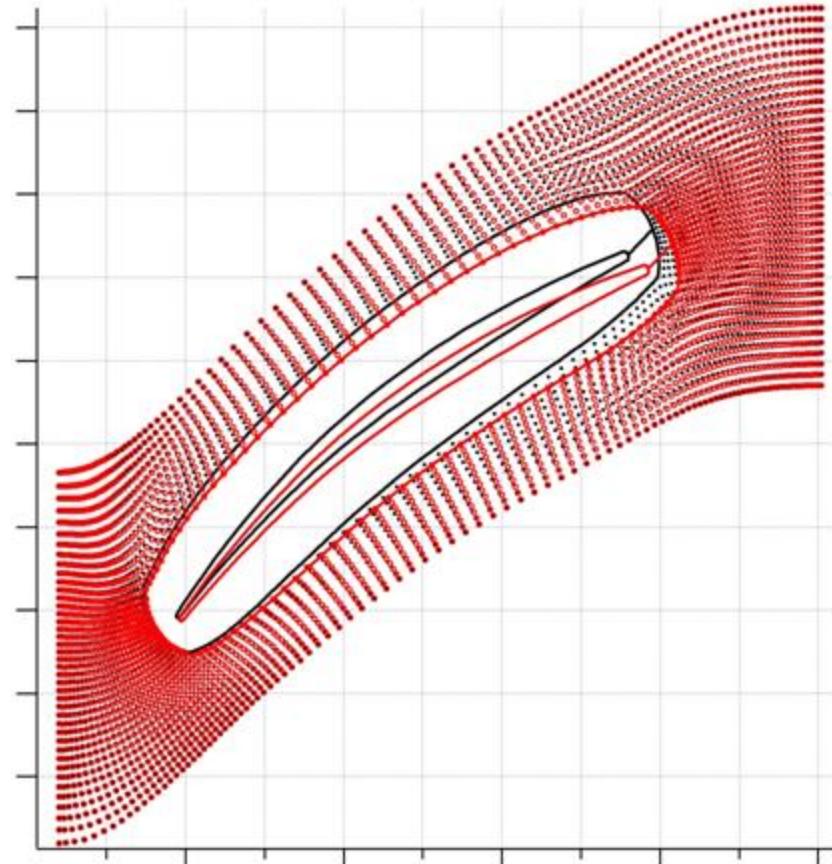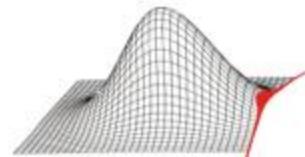
Distribution of result values

example: Isentropic efficiency
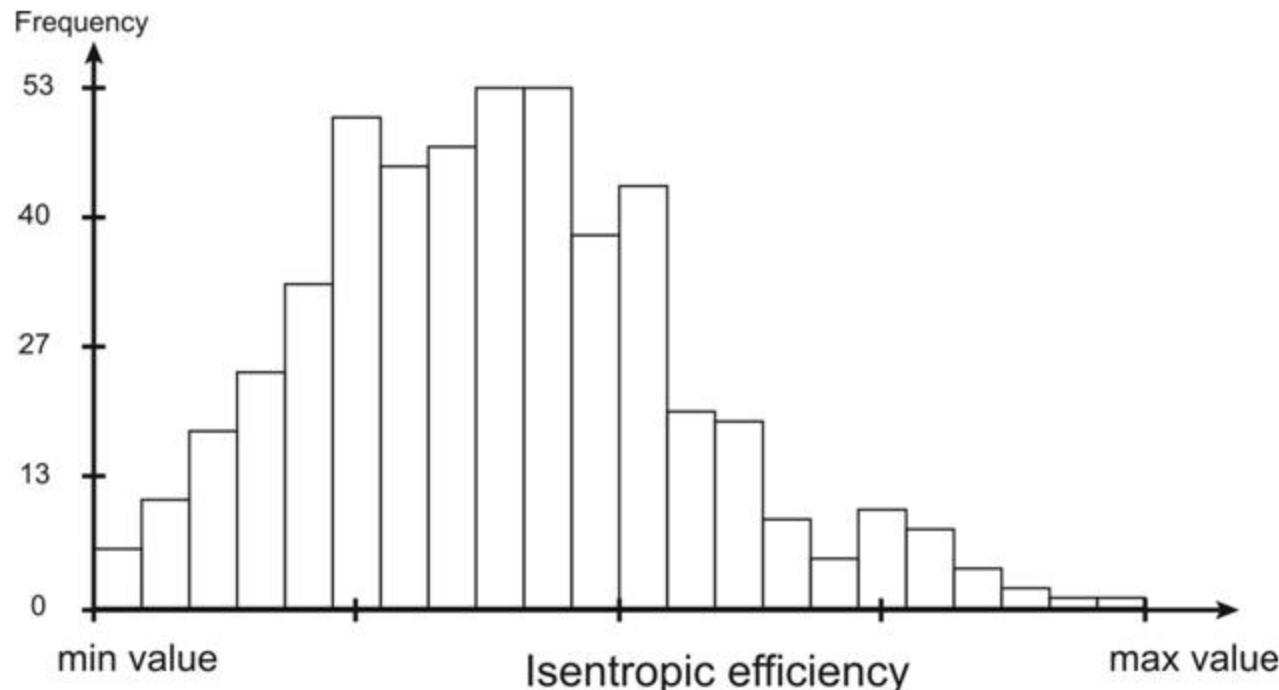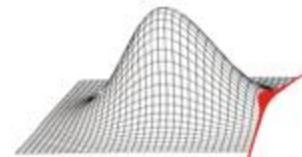
Correlation coefficients: input vs. output variables
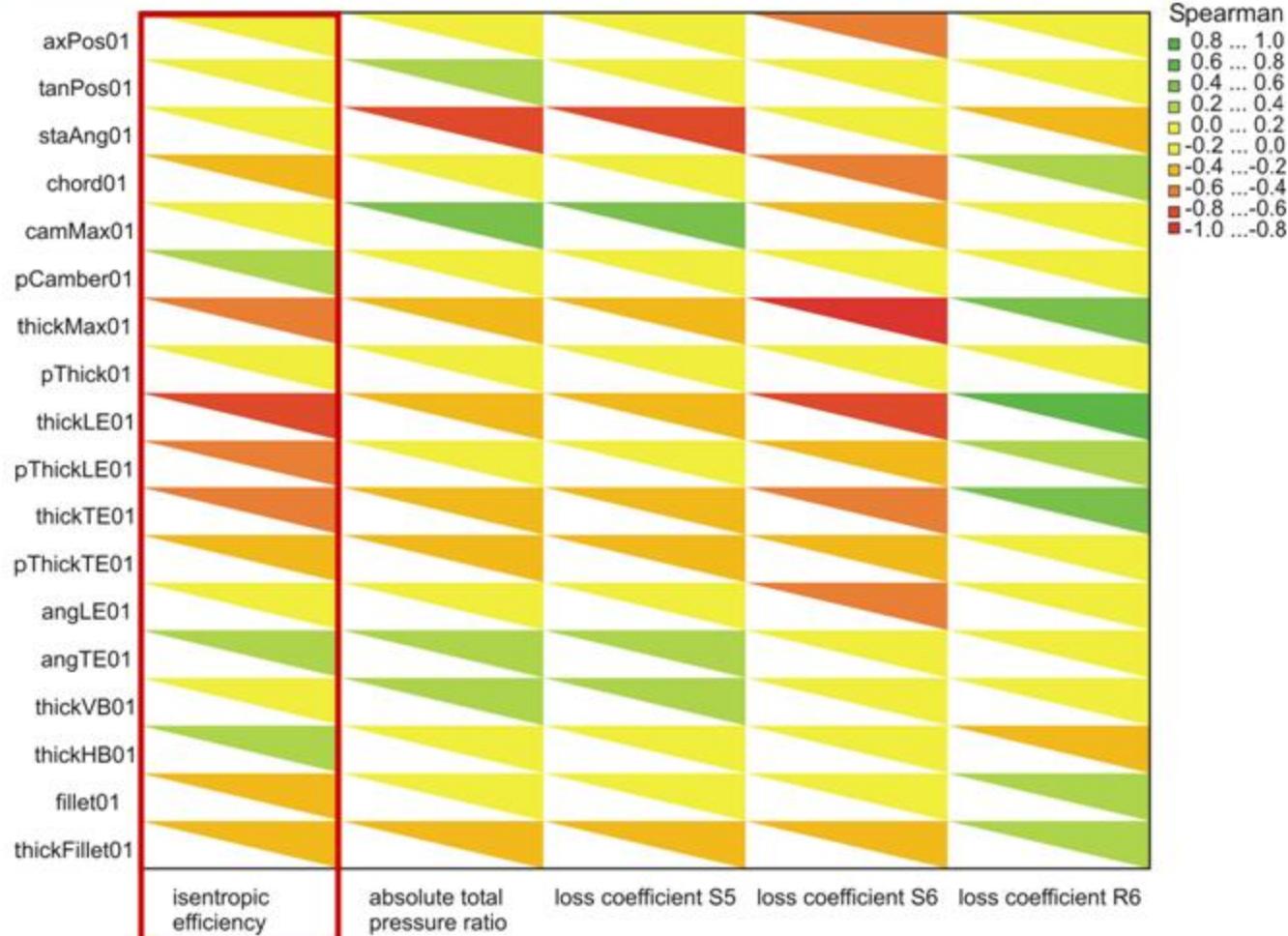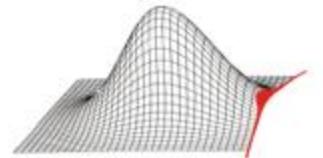
pie chart

Target-Variable: Isentropic efficiency
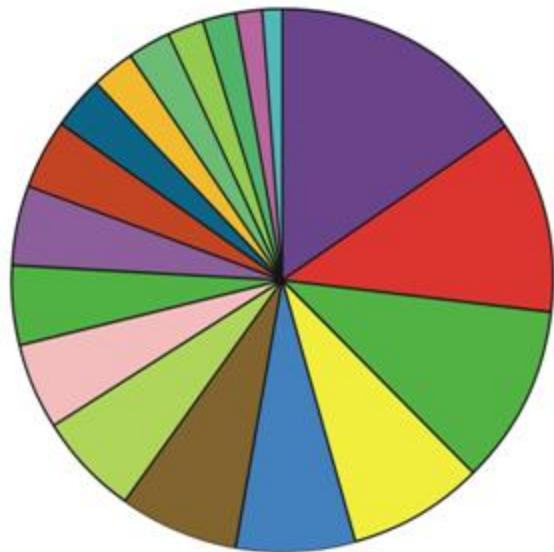
Legend:
- thickLE01
- thickMax01
- thickTE01
- pThickLE01
- pThickTE01
- thickFillet01
- chord01
- angTE01
- thickHB01
- fillet01
- pCamber01
- staAng01
- angLE01
- tanPos01
- thickVB01
- pThick01
- camMax01
- axPos01

- max efficiency
- min efficiency
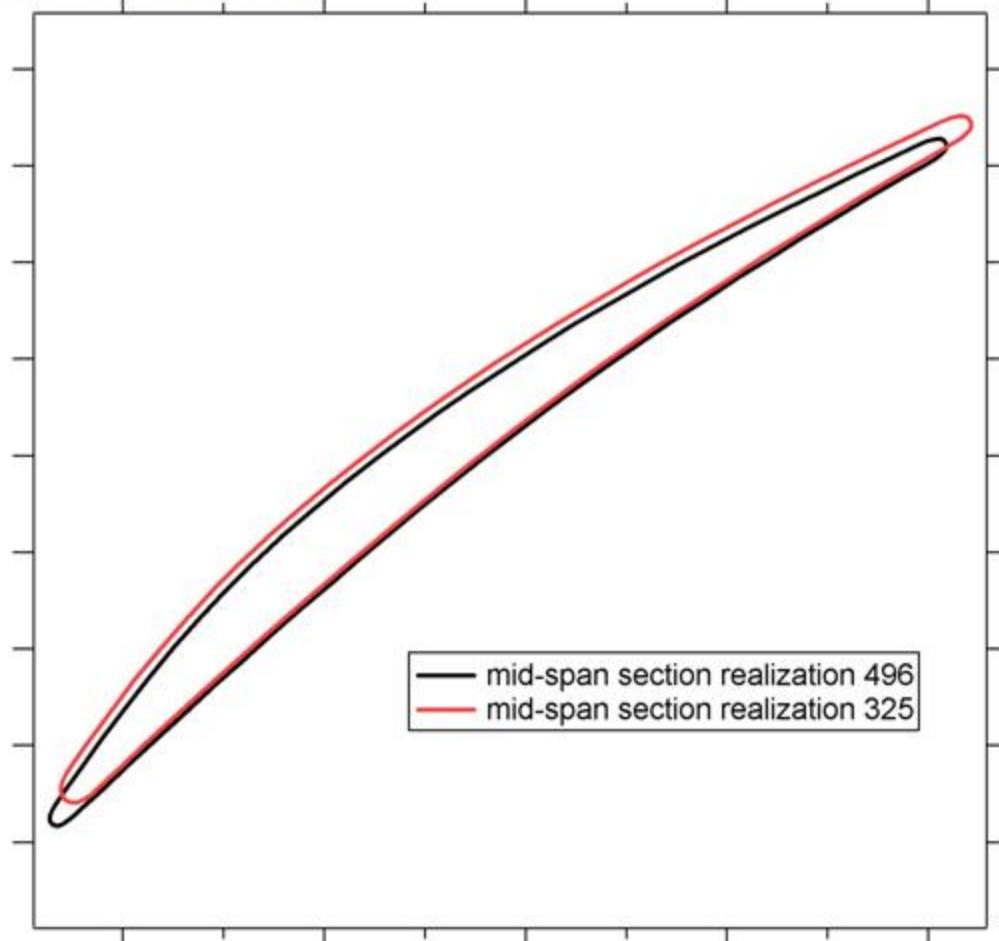
y-axis: thickness of LE
x-axis: maximum thickness

mid-span section

analysis of 2 blades:
realization 325
• thick blade
• low efficiency
realization 496
• thin blade
• high efficiency

— mid-span section realization 496
— mid-span section realization 325
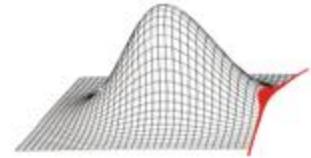
static pressure at mid-span
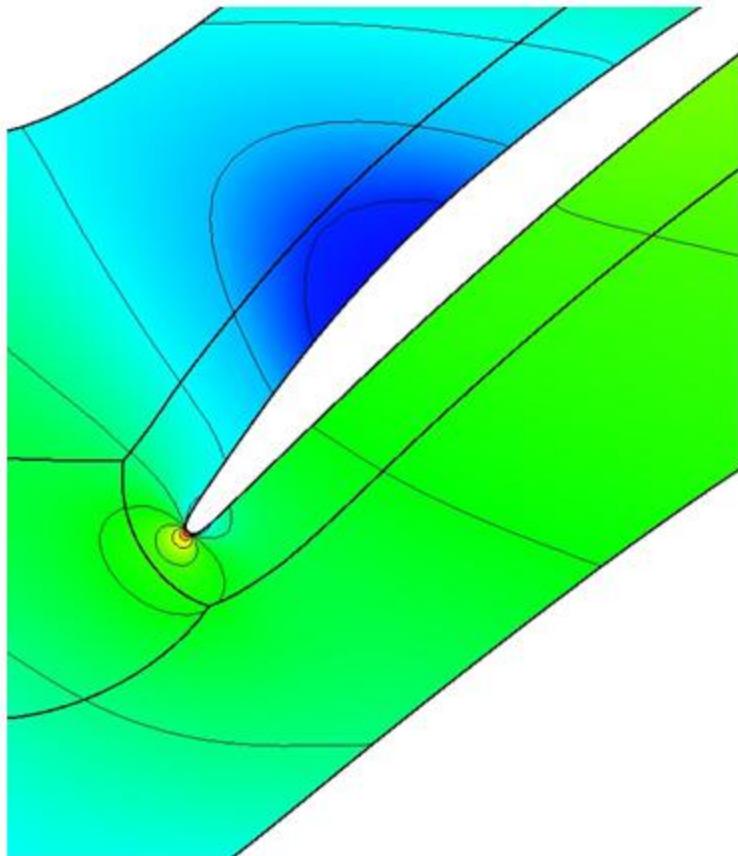
rel 496
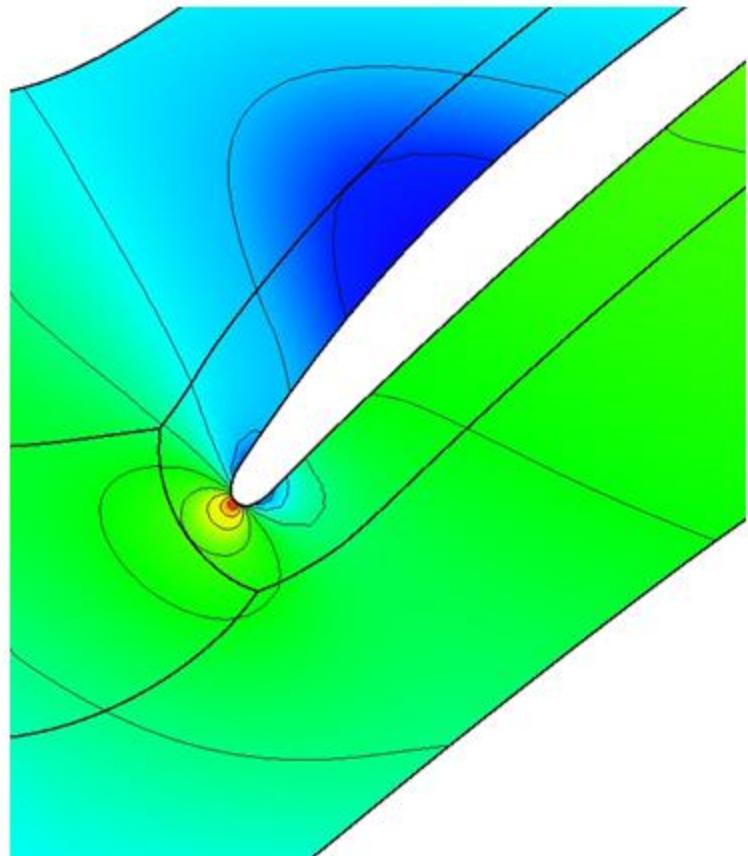
rel 325
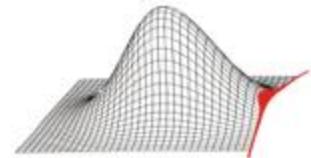
static pressure on blade surface (mid-span)
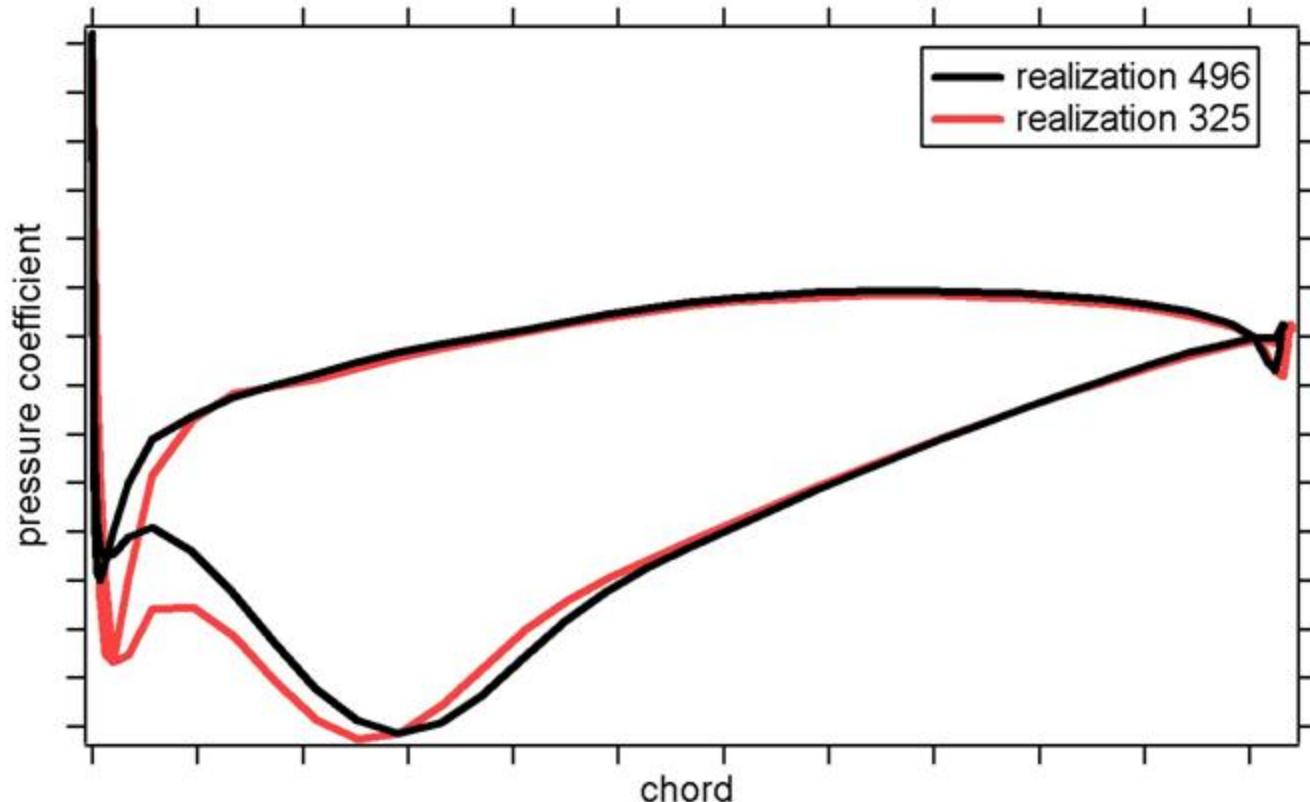
analysis of 2 blades:
realization 325
•thick blade
•low efficiency
realization 496
•thin blade
•high efficiency

realization 496
realization 325

pressure coefficient
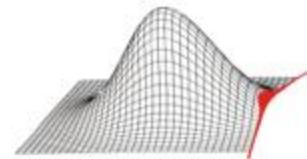
chord

pie chart analysis: isentropic efficiency and loss coefficient


Target-Variable: Isentropic efficiency
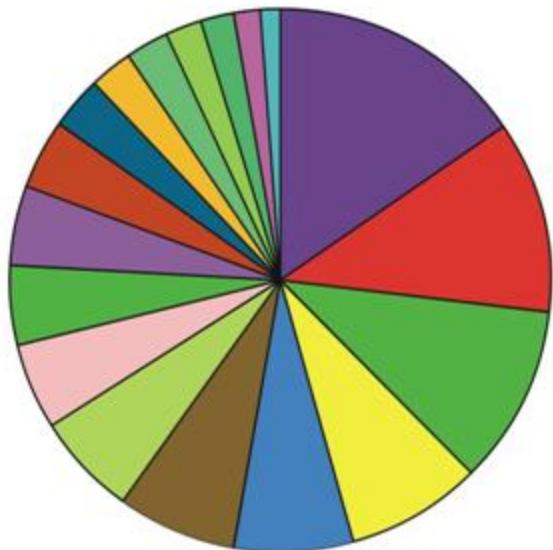
- thickLE01
- thickMax01
- thickTE01
- pThickLE01
- pThickTE01
- thickFillet01
- chord01
- angTE01
- thickHB01
- fillet01
- pCamber01
- staAng01
- angLE01
- tanPos01
- thickVB01
- pThick01
- camMax01
- axPos01

Target-Variable: loss coefficient R6
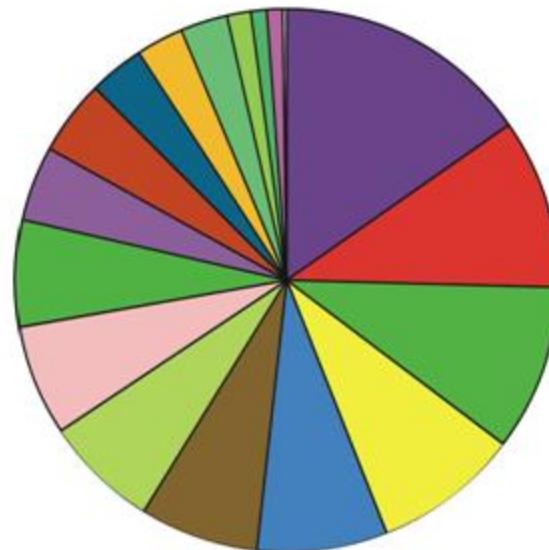
- thickLE01
- thickMax01
- thickTE01
- thickFillet01
- staAng01
- thickHB01
- pThickLE01
- fillet01
- chord01
- pThickTE01
- thickVB01
- angLE01
- pThick01
- angTE01
- pCamber01
- axPos01
- camMax01
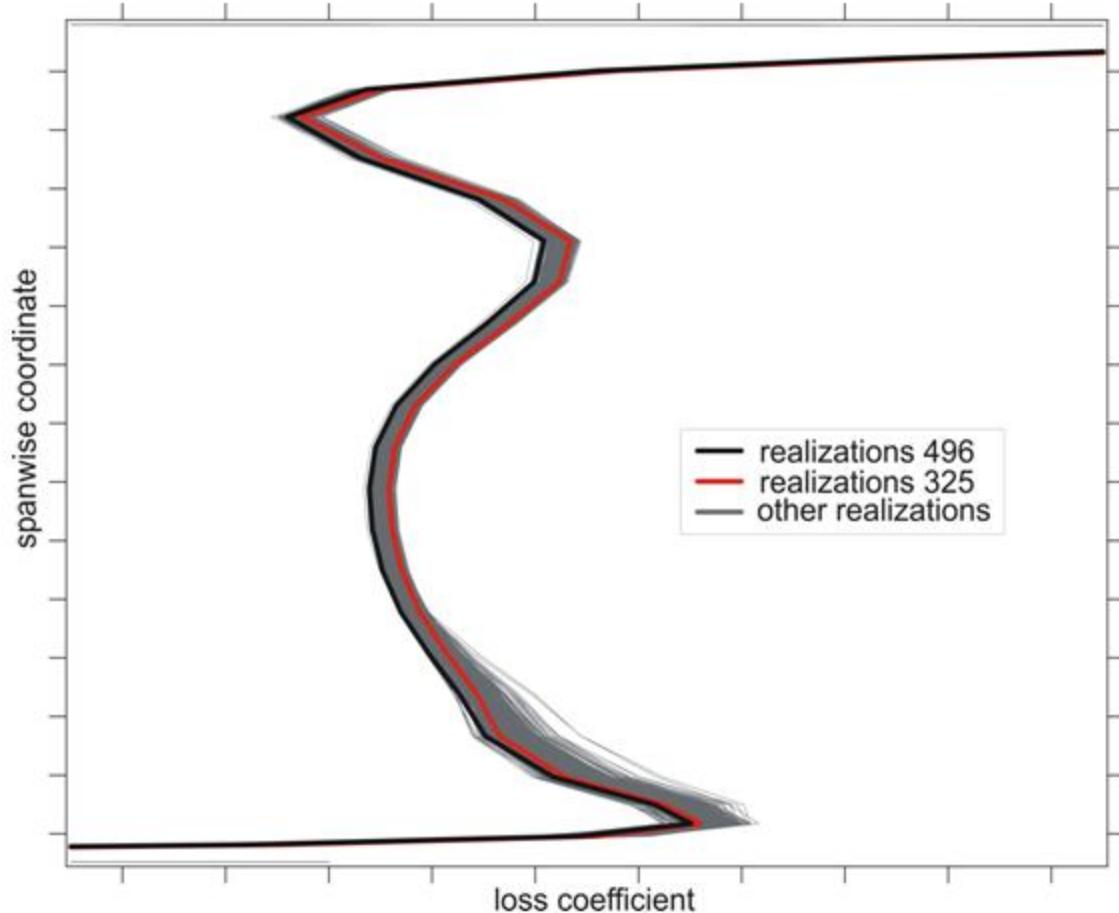
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loss coefficient

analysis of 2 blades:
realization 325
•thick blade
•low efficiency
realization 496
•thin blade
•high efficiency

Legend:
— realizations 496
— realizations 325
— other realizations

*Axes: spanwise coordinate (vertical), loss coefficient (horizontal)*

sensitivity of loss coefficient to fillet parameters

analysis of 2 blades:
realization 380
• small fillet
• lower loss coefficient
realization 185
• big fillet
• higher loss coefficient

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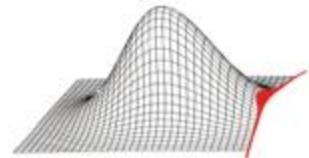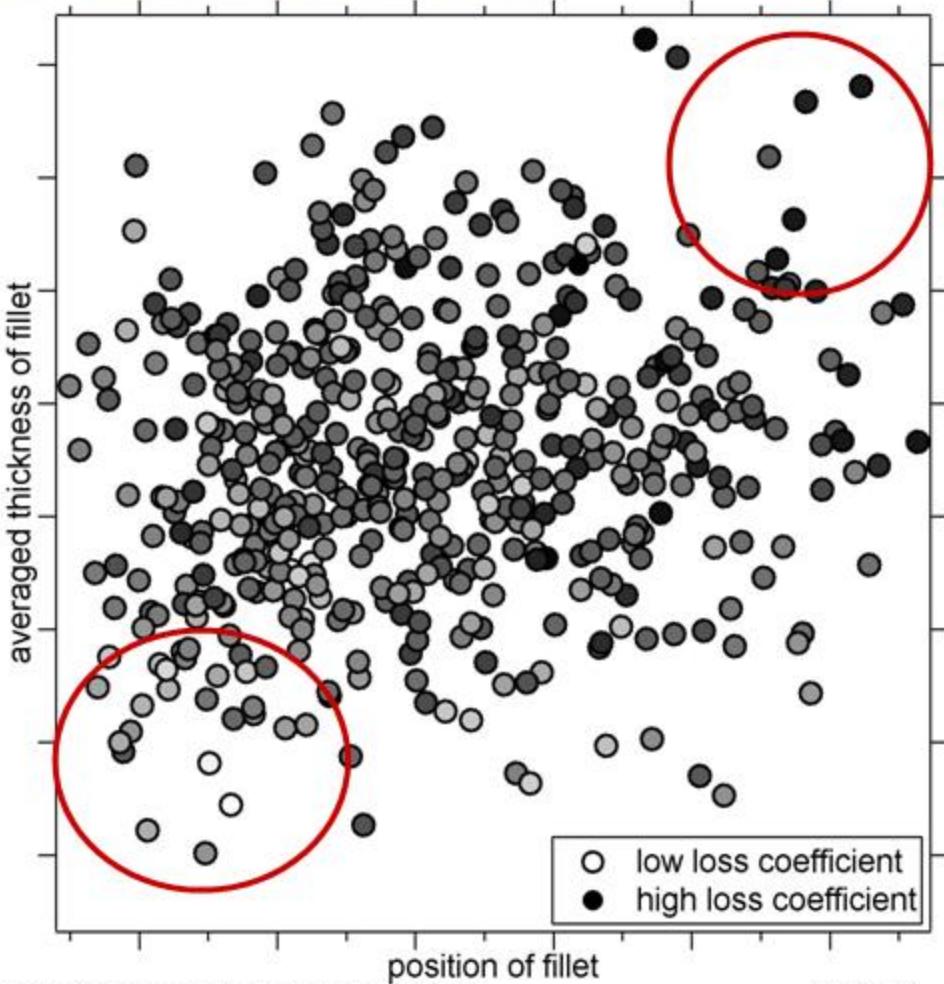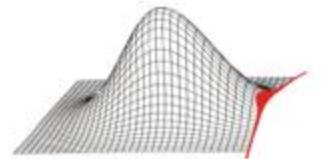
thickness distribution: two selected realizations
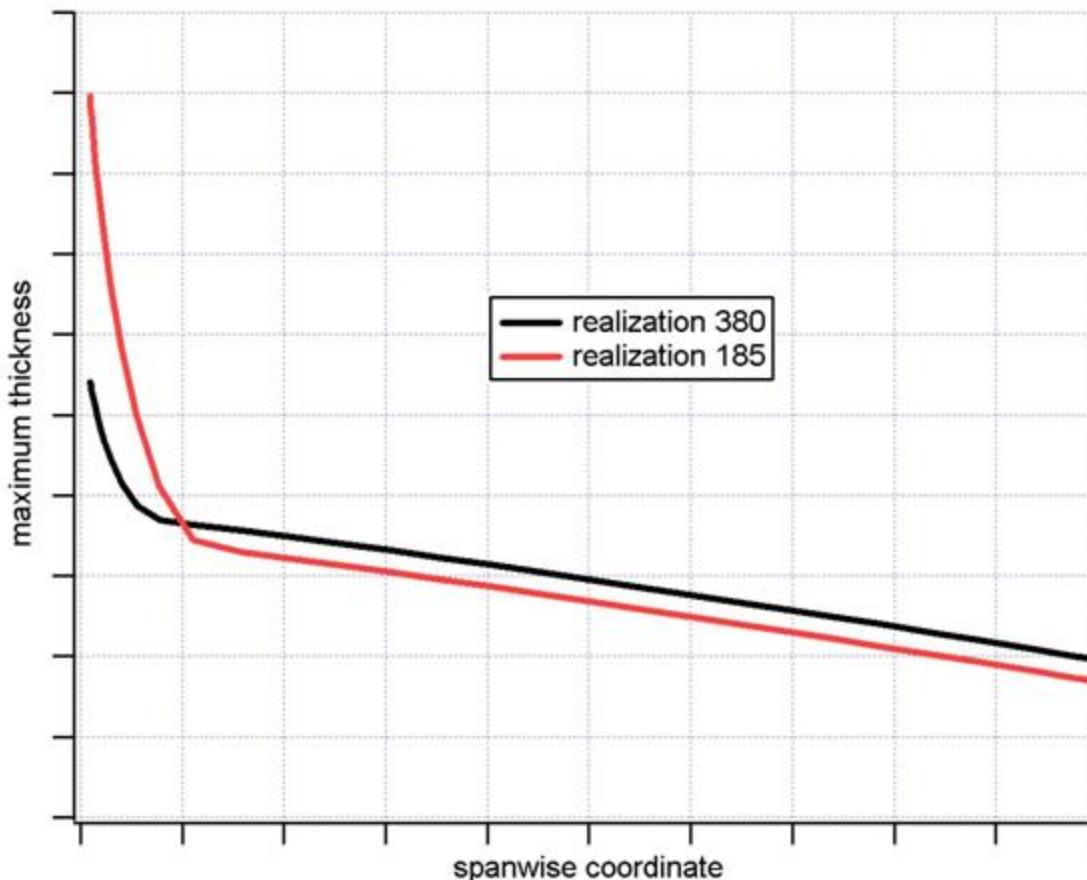

analysis of 2 blades:
realization 380
•small fillet
•lower loss coefficient
realization 185
•big fillet
•higher loss coefficient
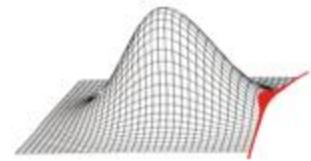
radial velocity: two selected realizations
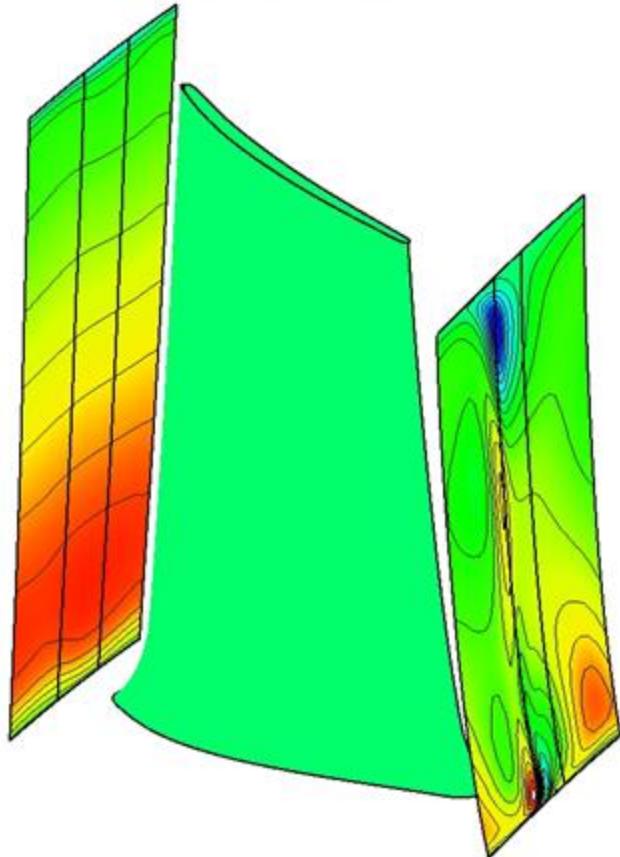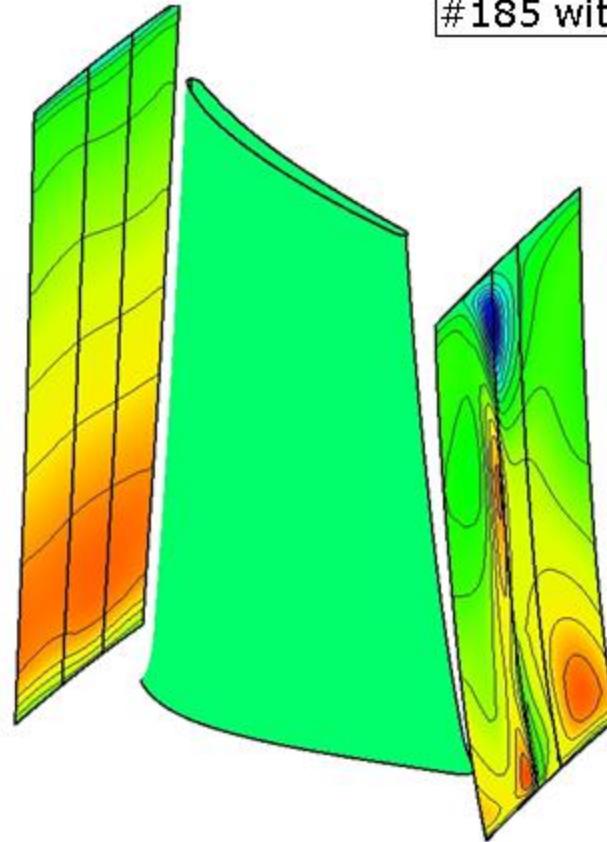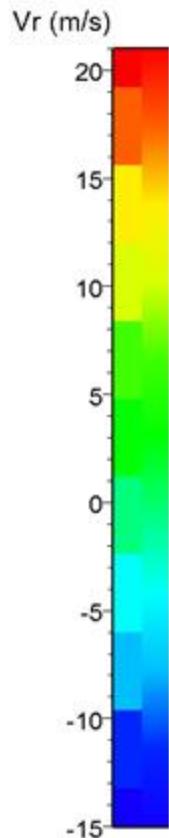
analysis of 2 blades:
#380 with small fillet
#185 with big fillet


Vr (m/s)

rel 185

rel 380

sensitivity of loss coefficient to fillet parameters


analysis of 2 blades:
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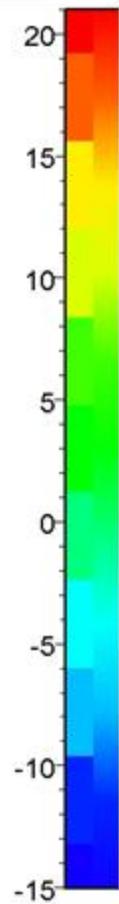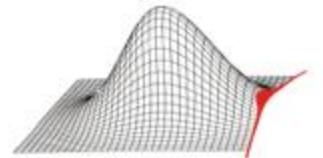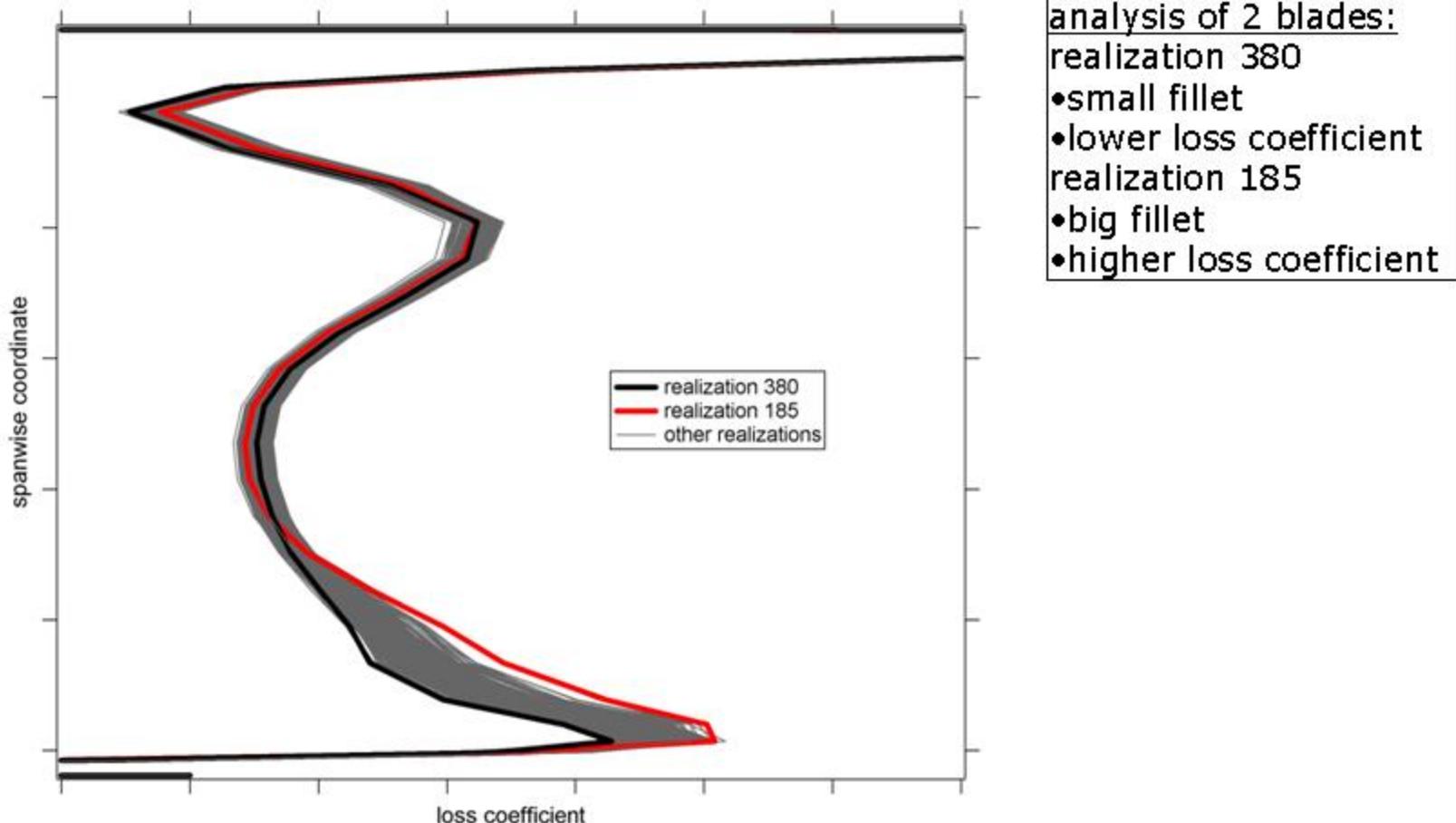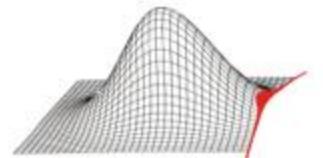
further probabilistic Simulation

- HPC-stage analysis with up to 15 individual blades

→ 15*16=240 probabilistic variables used

→ investigation of non-axial symmetric effects

→ developed morphing approach allows quick grid generation

Static Pressure (Pa)

200000
180000
160000
140000
120000
100000
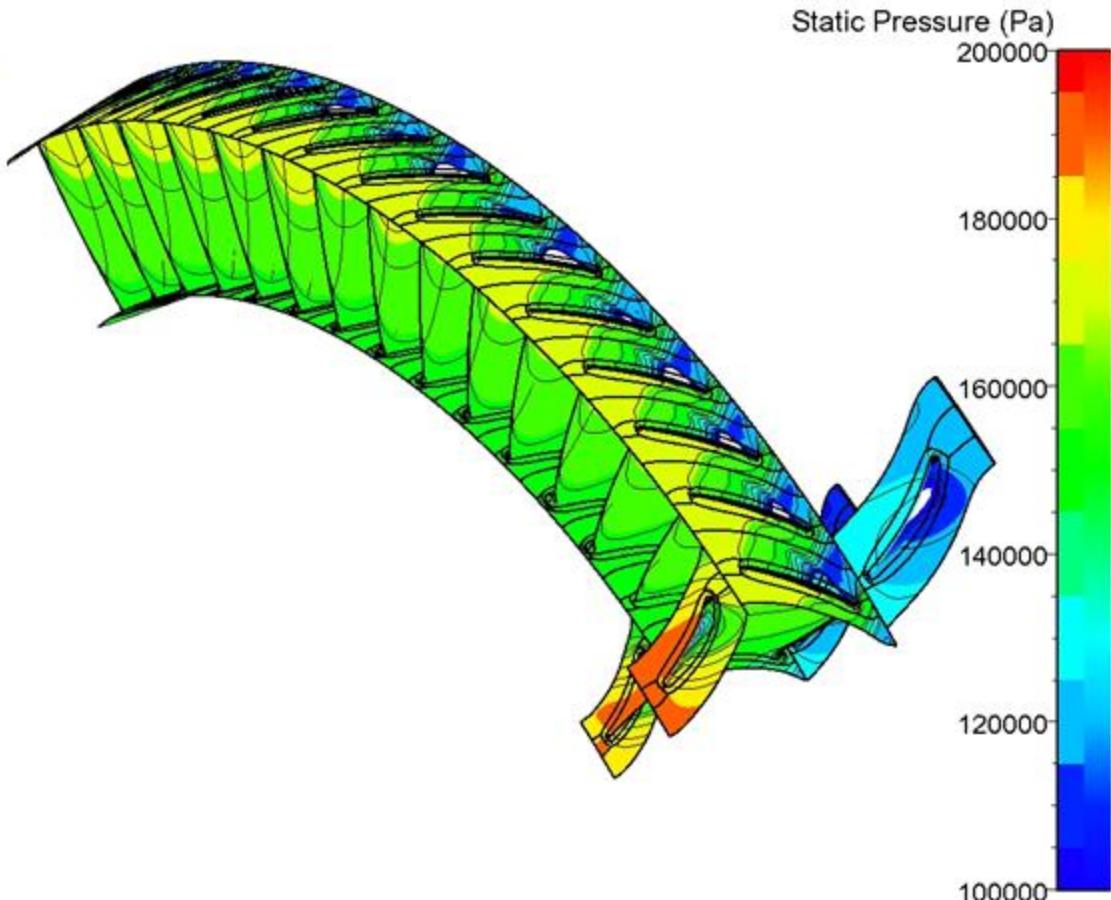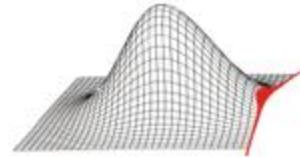
Thank you for your Attention!