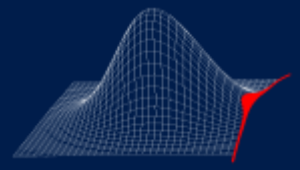
TECHNISCHE UNIVERSITÄT DRESDEN

Faculty of Mechanical Engineering · Institute of Fluid Mechanics · Chair of Turbomachinery and Jet Propulsion



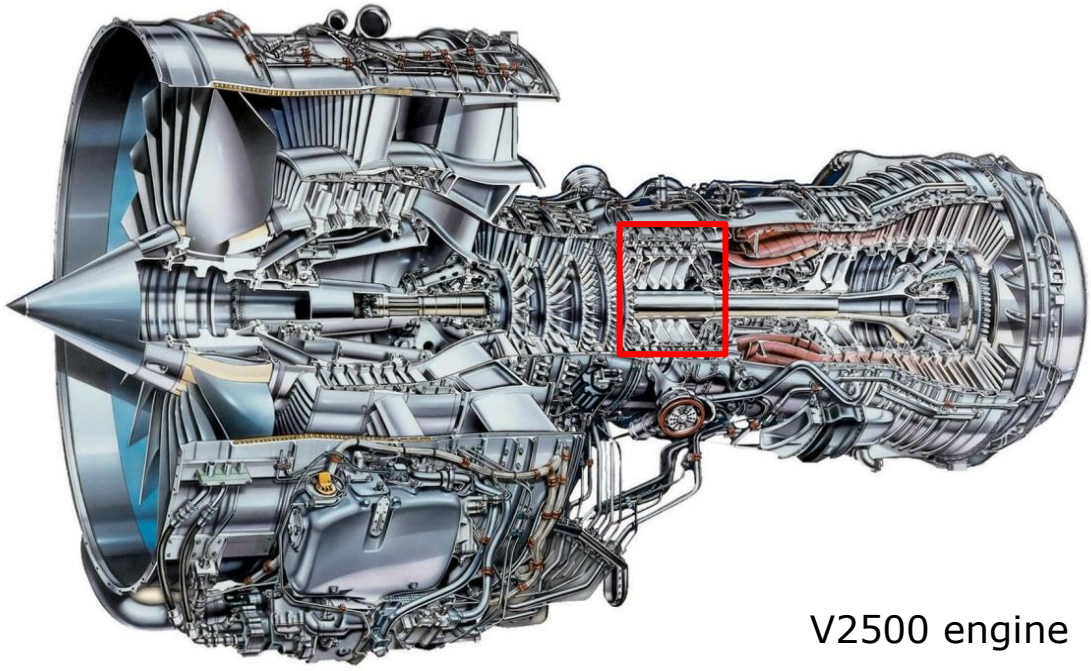
Probabilistic Structure-Mechanical Robustness Estimation of Rotor Discs Considering Geometry Variations

I. Reuter, M. Voigt , K. Vogeler - Technische Universität Dresden

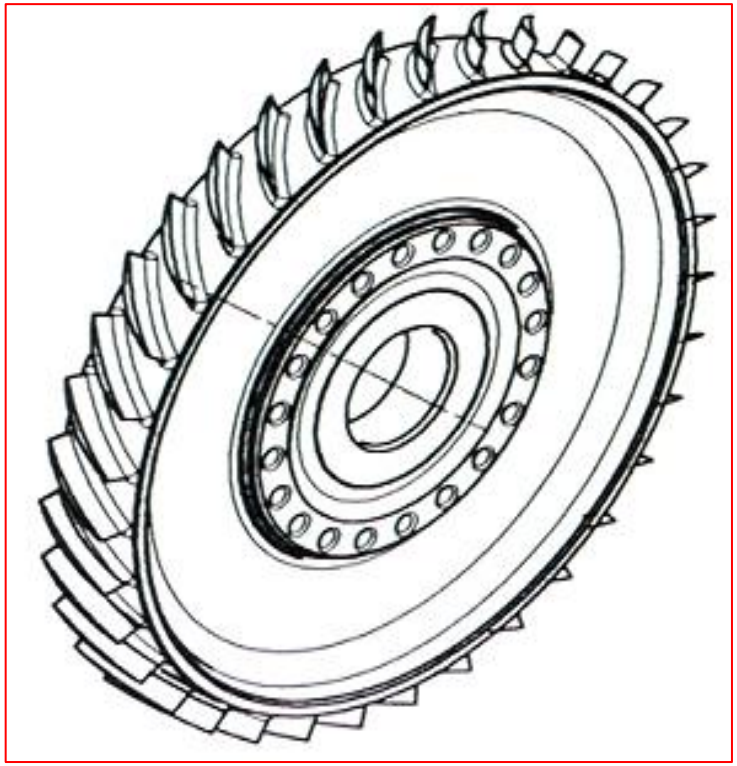
6. Dresdner Probabilistic-Workshop, 10th-11th October, 2013

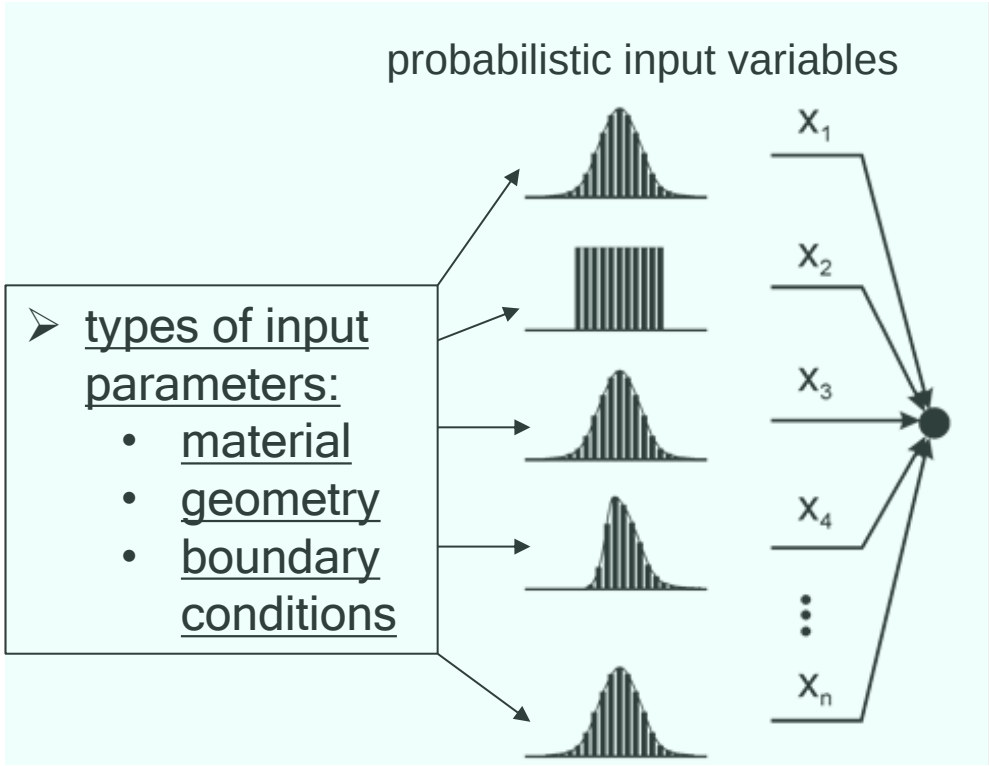
DRESDEN concept
Exzellenz aus Wissenschaft und Kultur

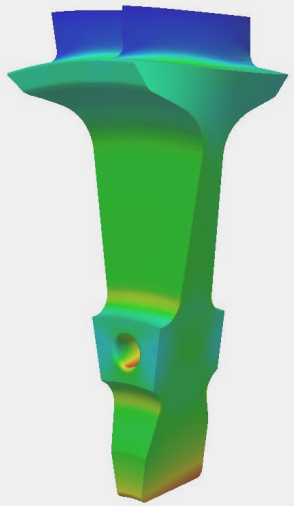
motivation - rotor disc

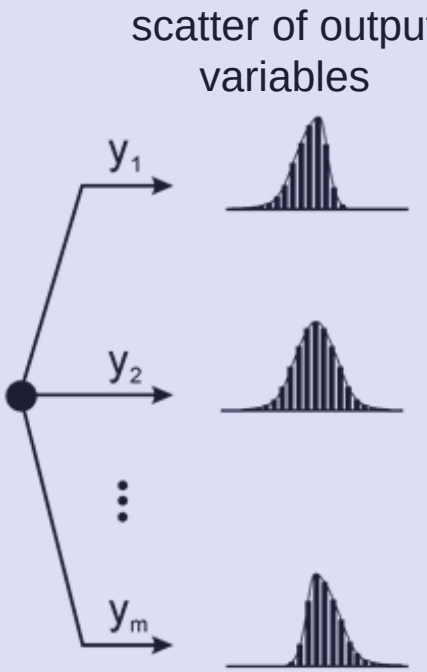


V2500 engine









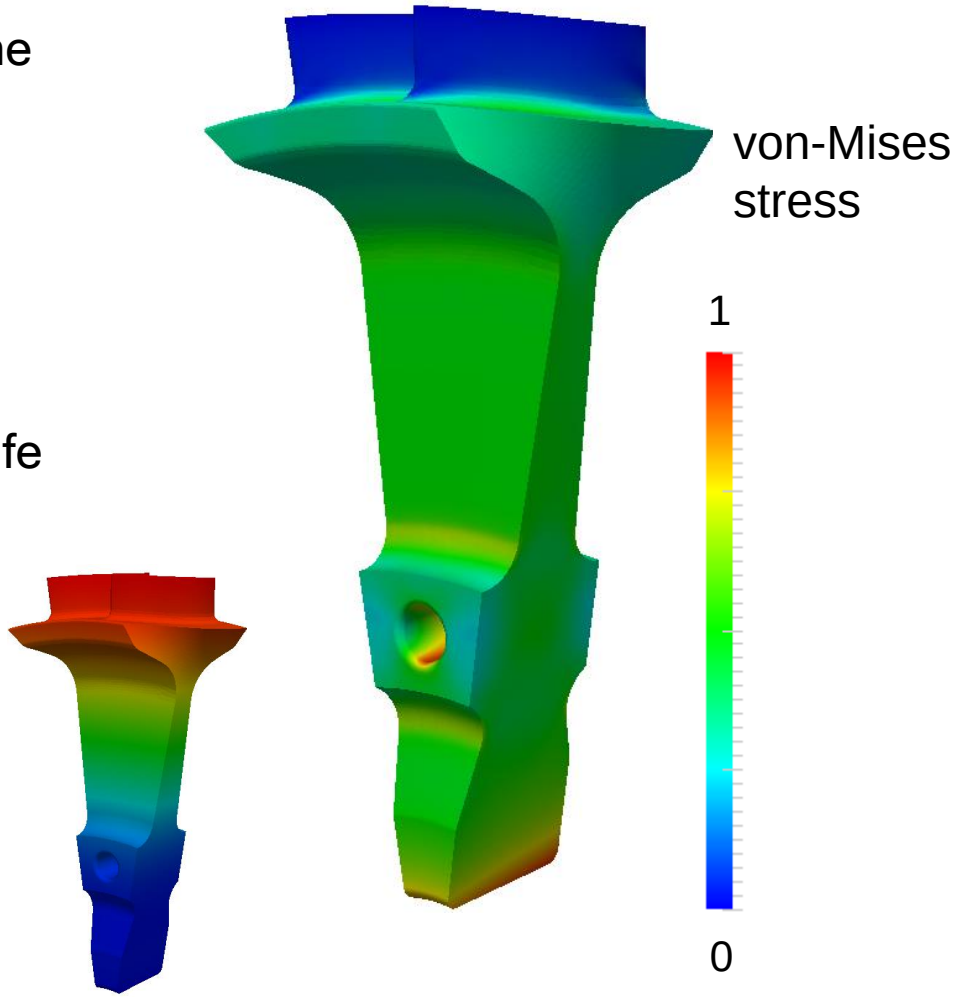
ProSi - PRE - EXE - POST

- sensitivity analysis
- system improvement and robustness estimation
- probability of occurrence

deterministic model

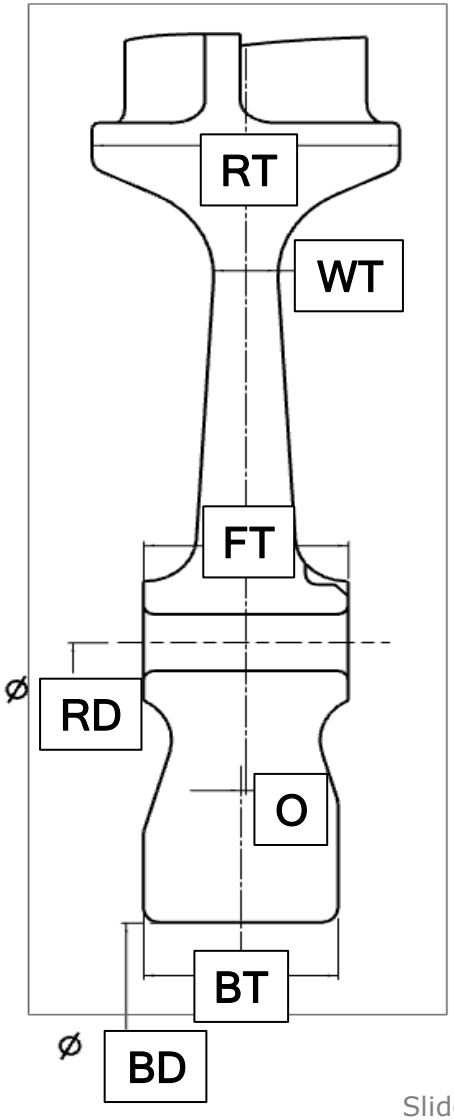
- FE-model provide by MTU Aero Engine
- based on test rig – spin test disc
  - blisk construction
  - material Ti6246
  - integrate dummyblades
  - 39000 rpm

- MTU-internal FE-solver Calculix and life time prediction with MTULife
- elastic analysis, one cycle
- 18° - 3D sector model
- ~ 900 000 nodes
- boundary conditions:
  - axial, tangential fixed
  - loads: rotating speed, radial temperature distribution



probabilistic model

- input variables
  - 7 geometrical input parameter
  - uniformly distributed
  - given variation range:
    - manufacturing tolerance
    - range for design improvement
- result parameter
  - von-Mises stress
- Monte Carlo simulation
  - with optimized Latin Hypercube Sampling
  - 60 and 75 realizations
- using the probabilistic tool ProSi



parametrical geometry Unigraphics NX

variation file

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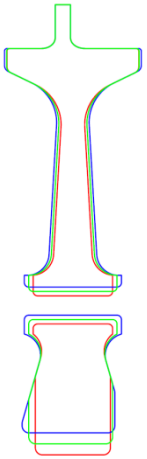
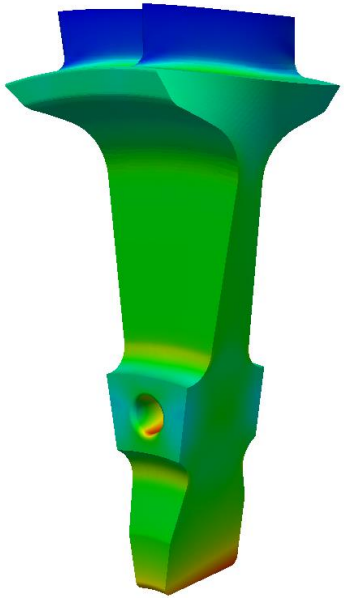
[mm]a3_BD=40
[mm]a4_RT=30
[mm]a5_TK=103
[mm]a6_O=0.5
[mm]a7_WT=6.4



export

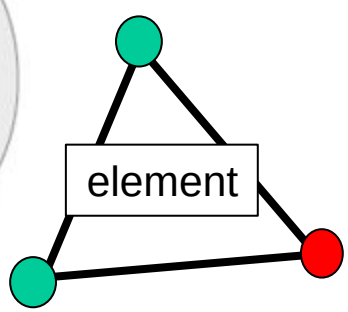
remeshing

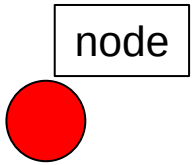
FE - calculation



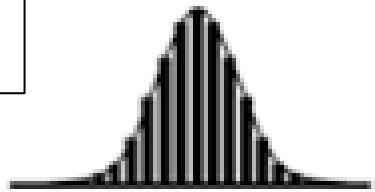
life time prediction

- result transfer of all MCS realizations on the evaluation mesh of a basic geometry



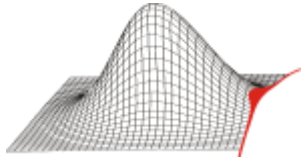


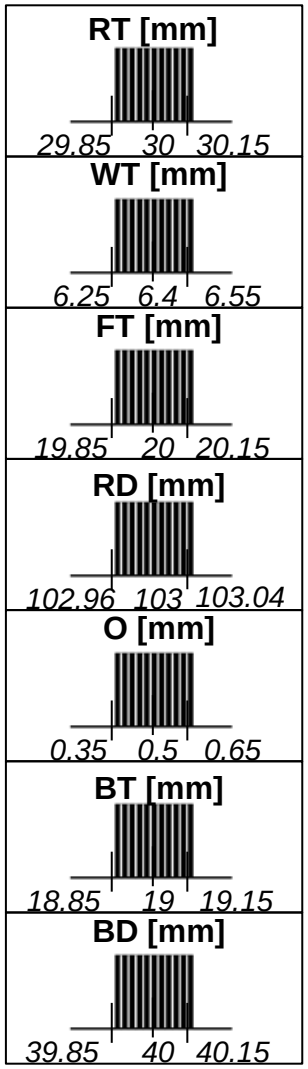
e.g. 50 Mises stress values per node

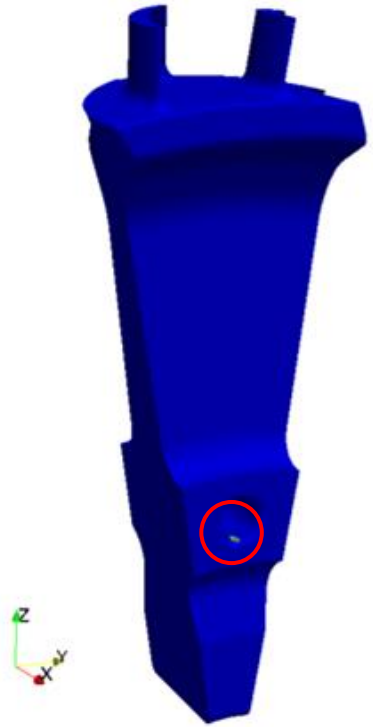


- Calculation of:
  - mean value
  - standard deviation
  - Spearman rank coefficient of correlation
  - relative frequency
  - response surface

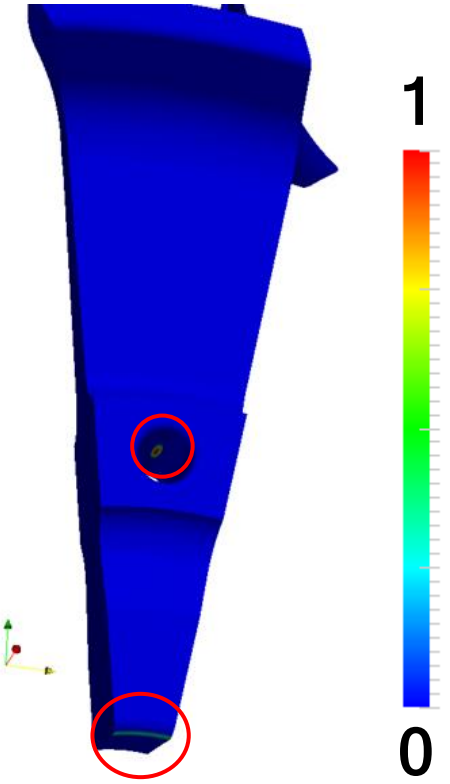
MCS manufacturing tolerances



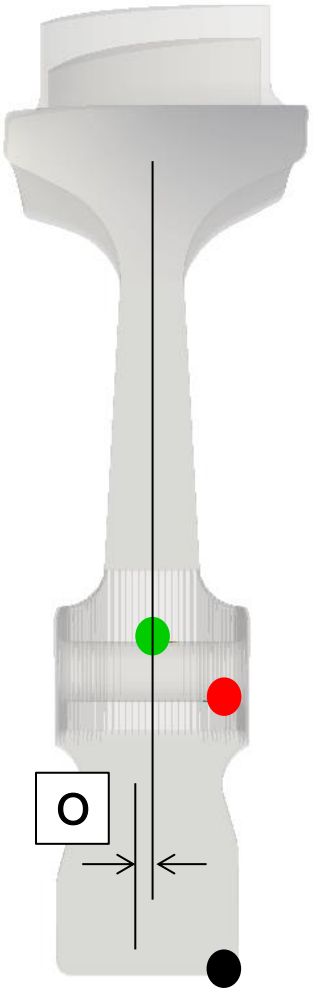


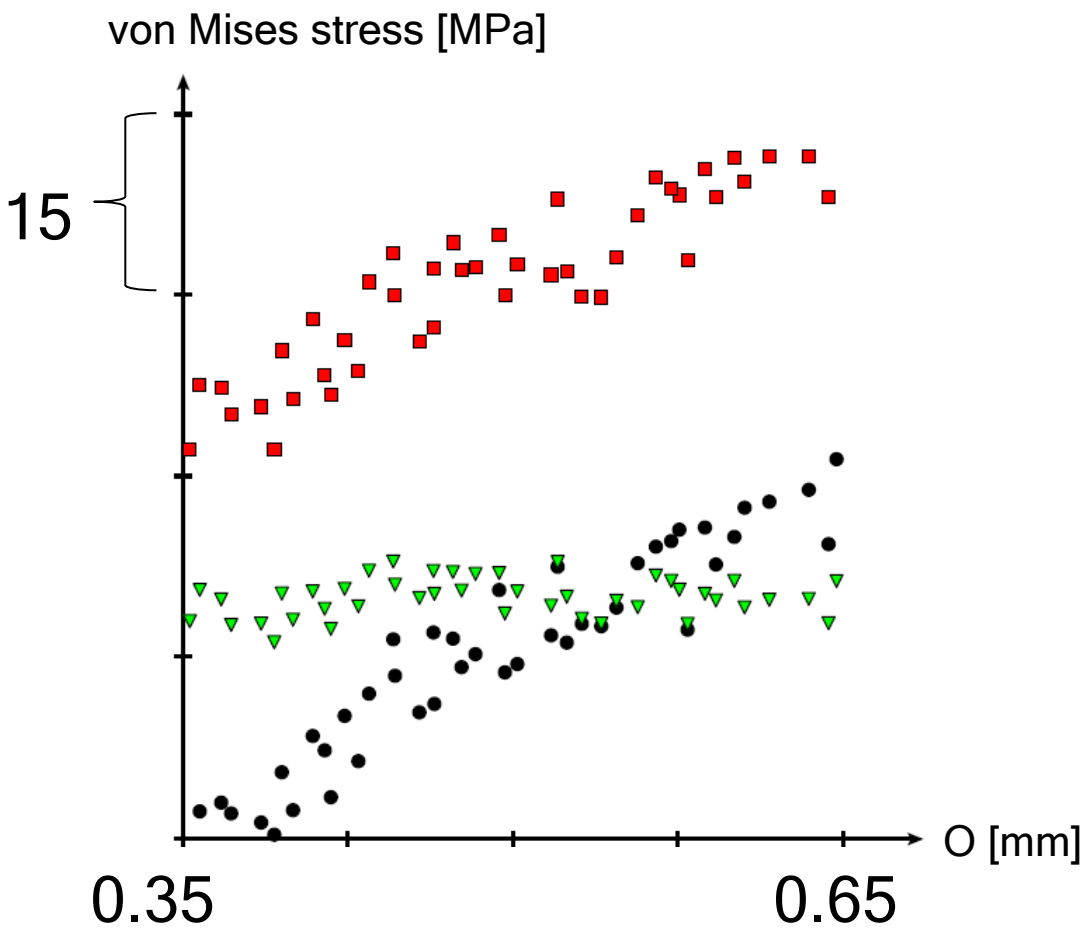


relative frequency:
von Mises > limit



- offset parameter large influence

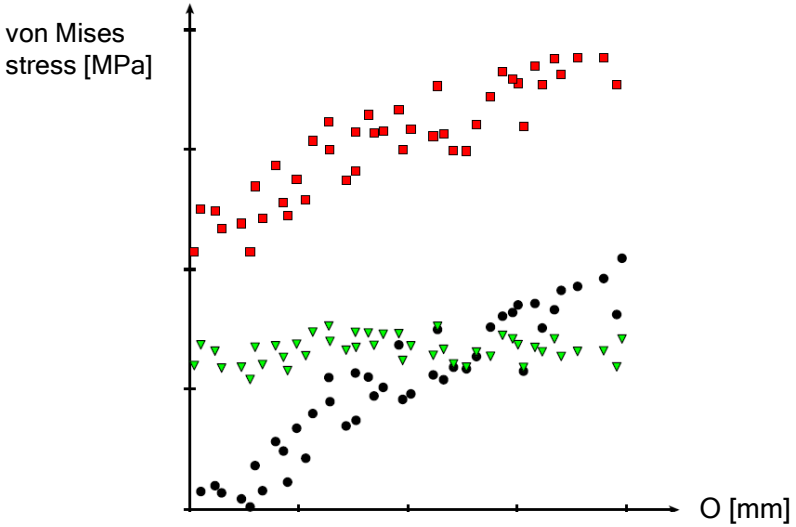


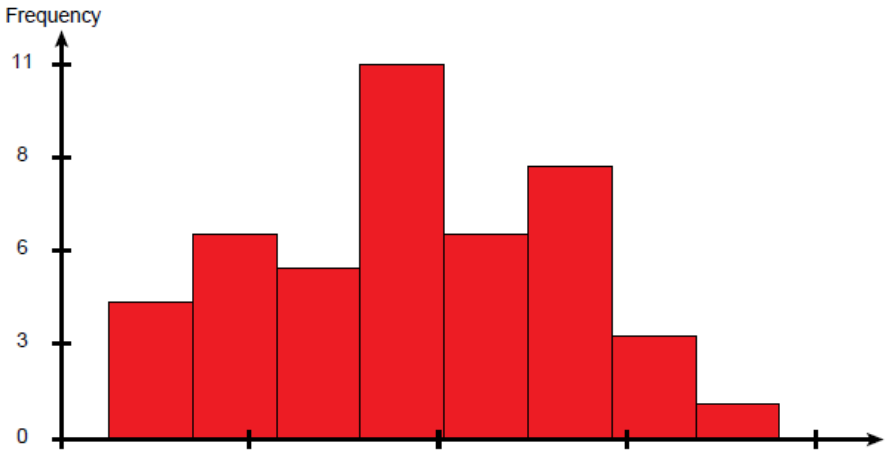


robust design baseline

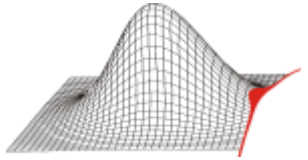
engineering characteristic	statistic characteristic
- exceed of limit values - occurence of sudden changes in results variables - occurence of system instabilitys	- position of mean value - amount of the coefficient of variation - in results variables

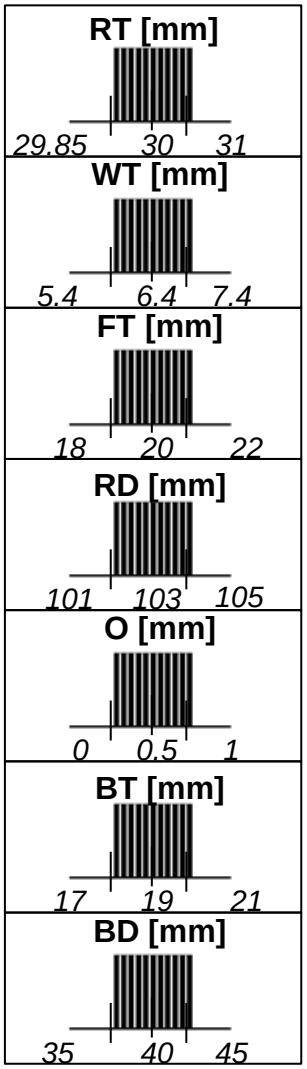
[1]

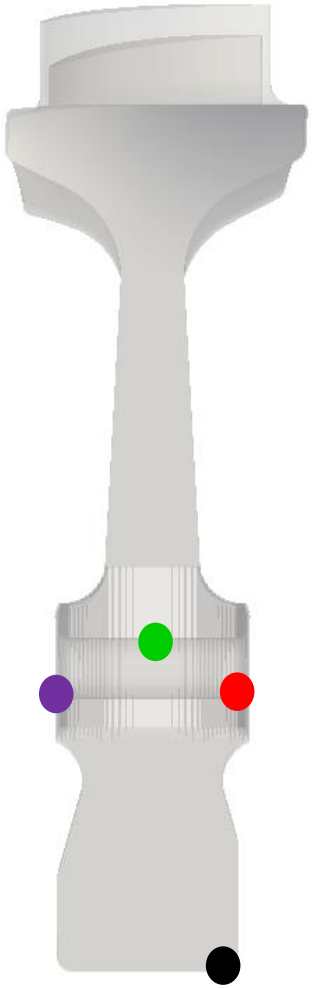


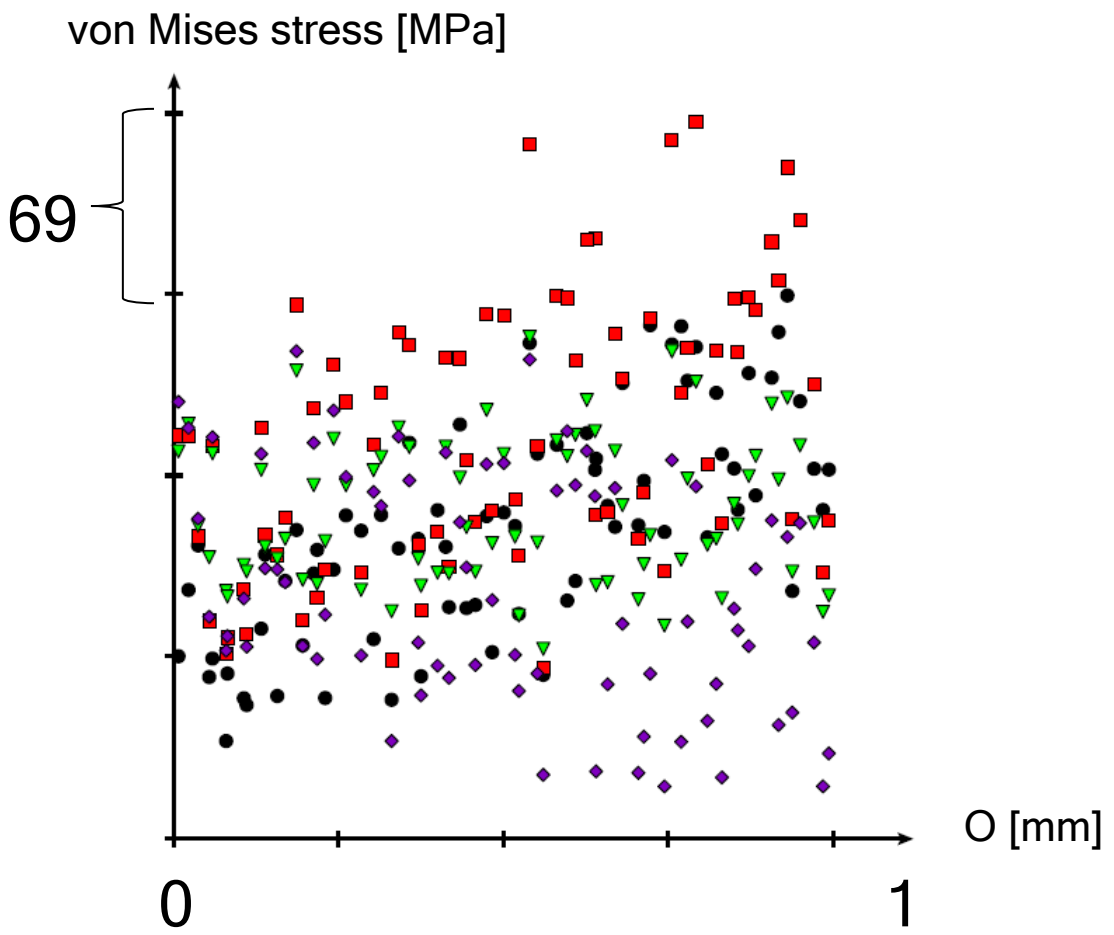


MCS with parameter range for design improvement

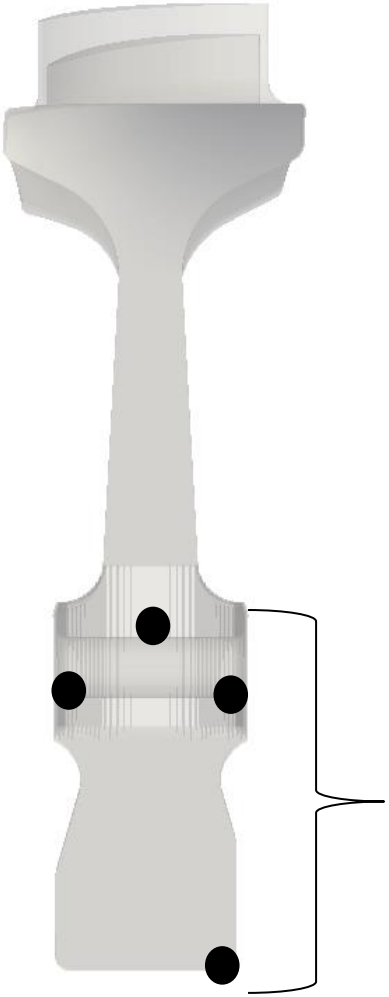




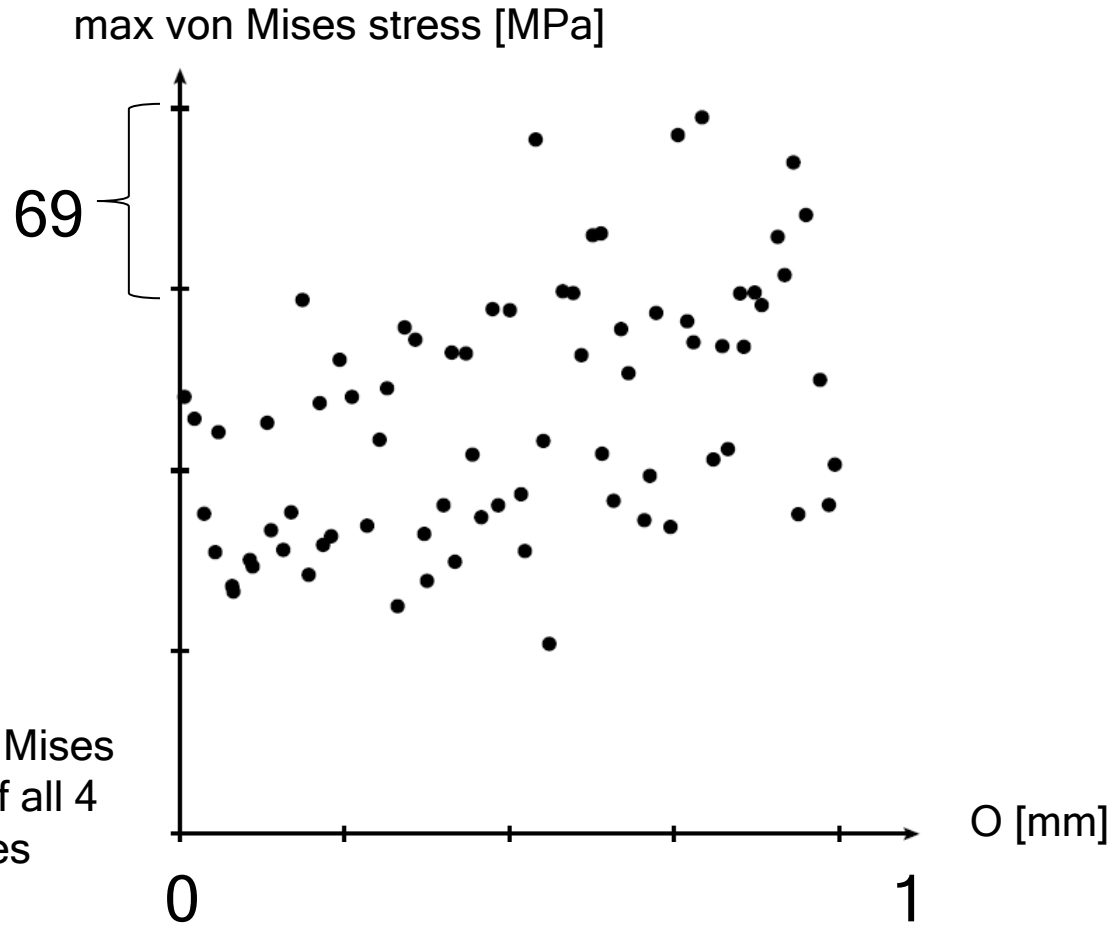




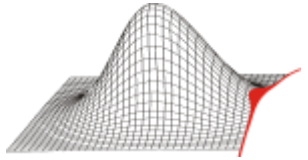
- MCS with variation range for system improvement



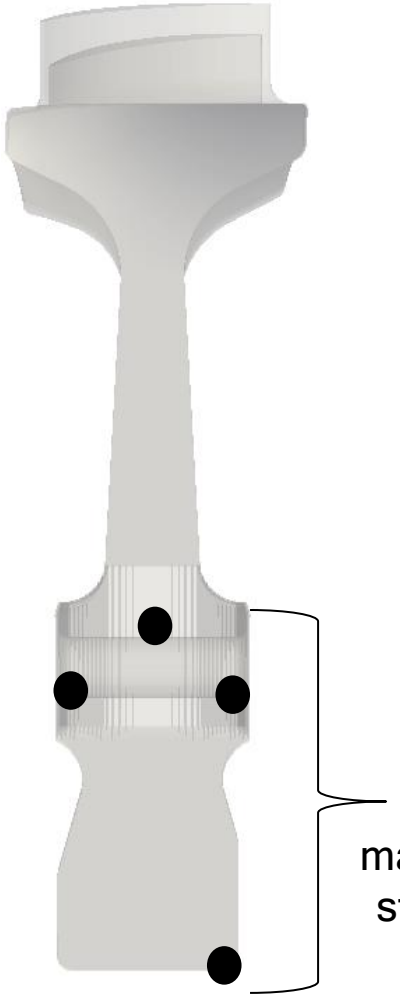
max von Mises stress of all 4 nodes



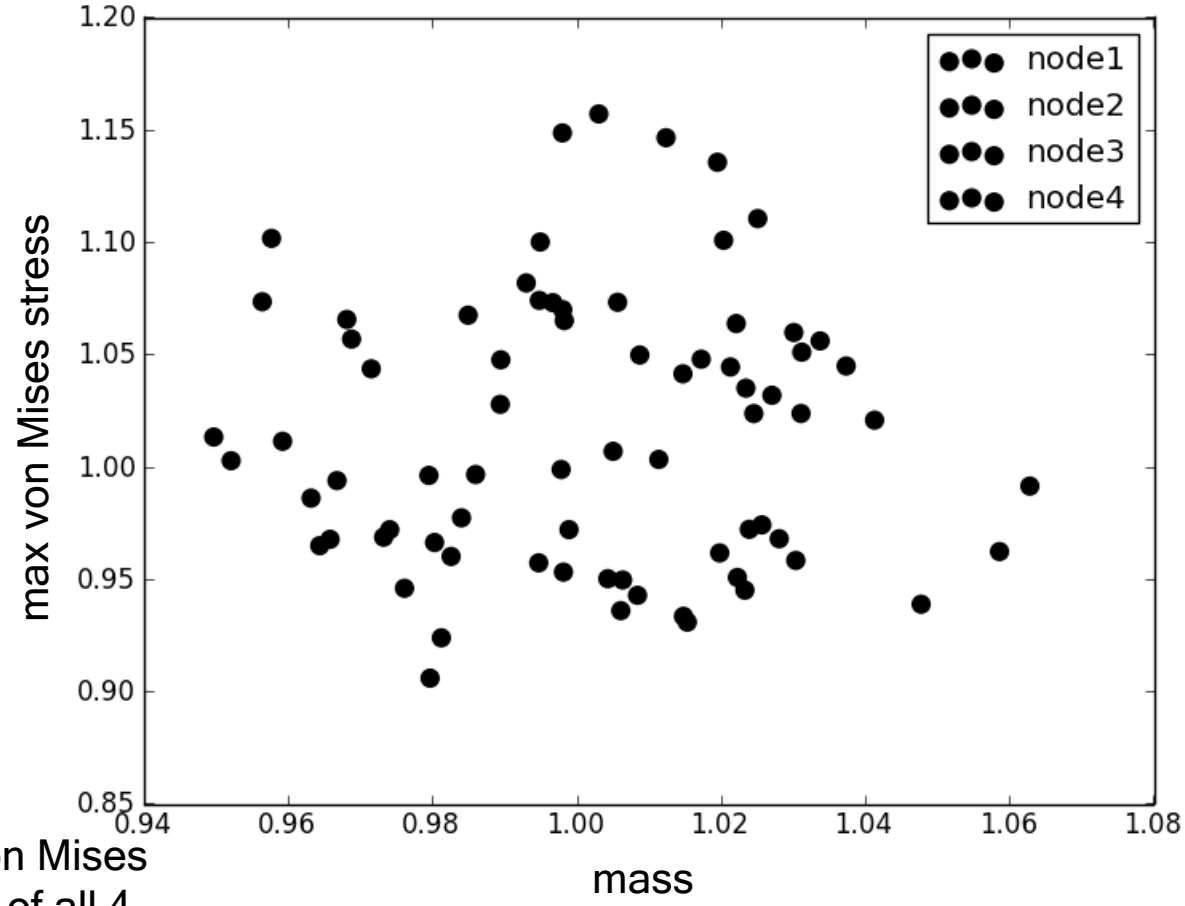
MCS with parameter range for design improvement



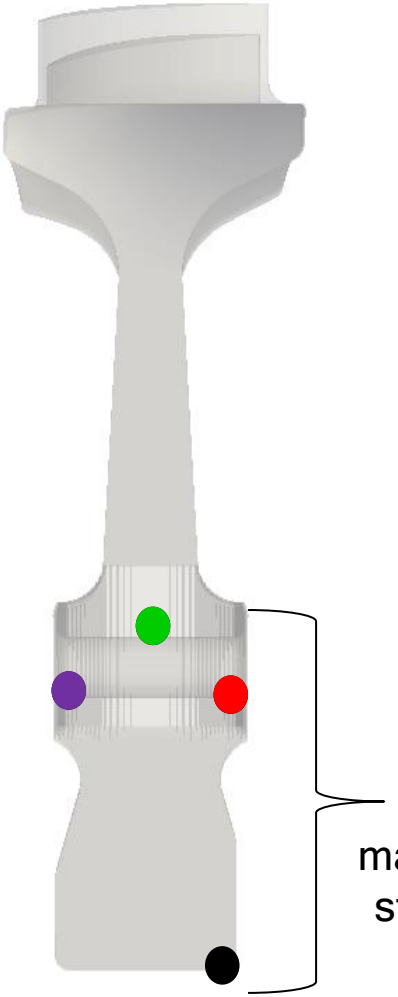
- MCS with variation range for system improvement



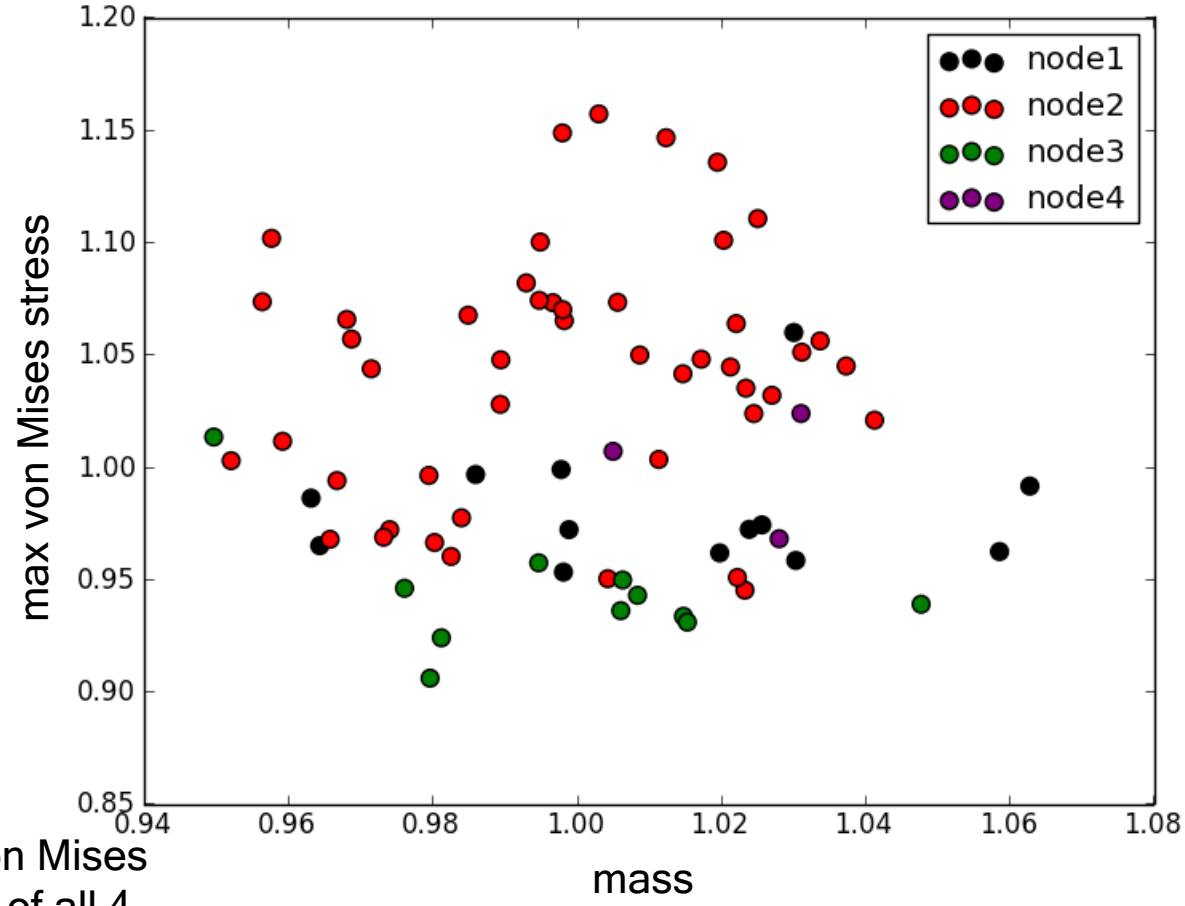
max von Mises stress of all 4 nodes

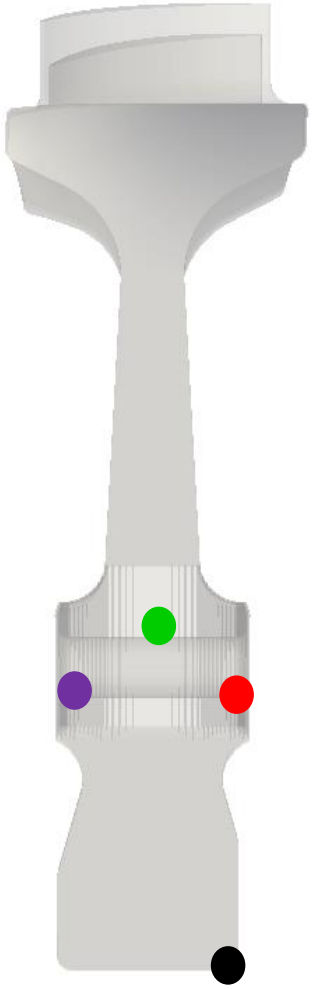


- MCS with variation range for system improvement

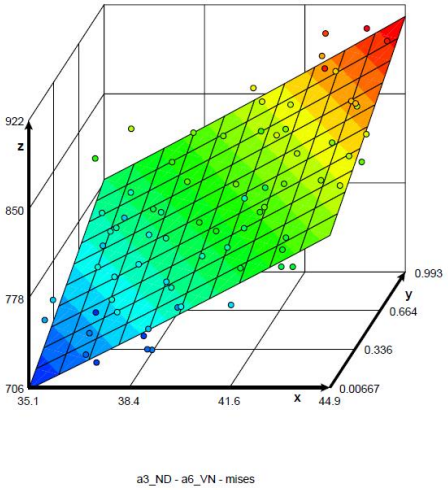


max von Mises stress of all 4 nodes



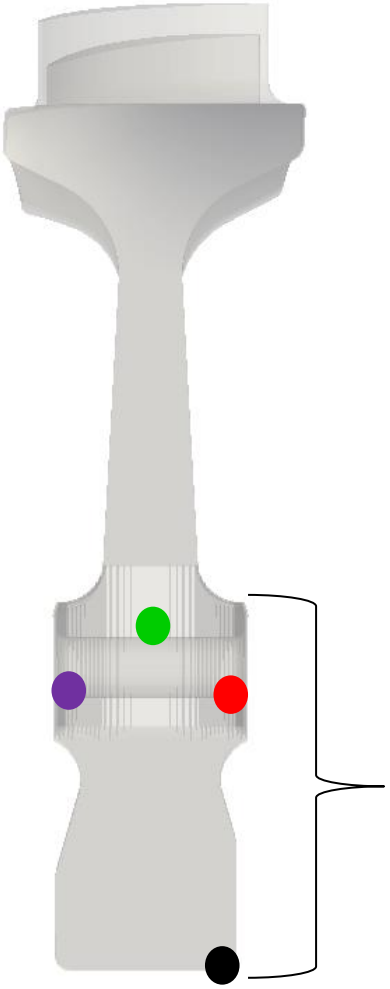


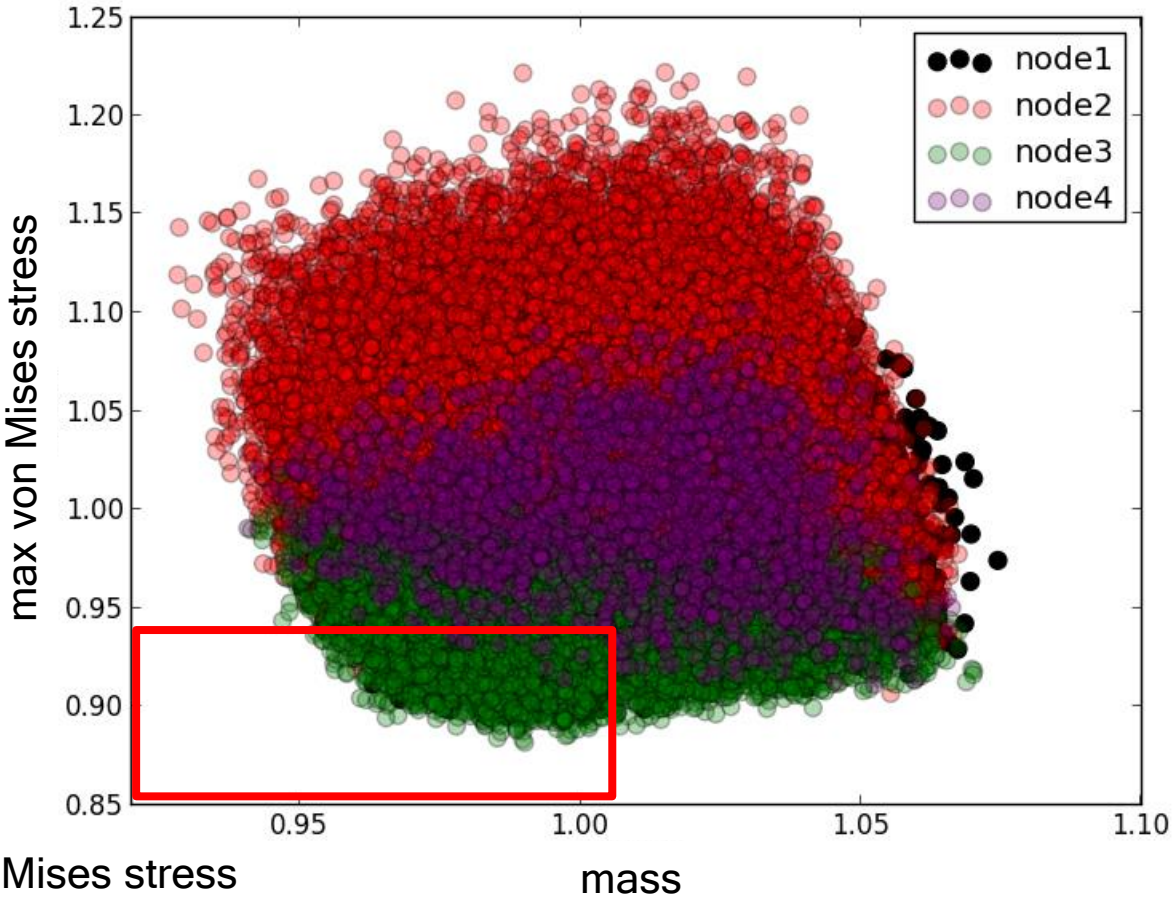
- for each node and rotor disc mass, one metamodel
- first order, linear behaviour



node	delta stress [MPa]	max error [MPa]	R^2
●	169	10	0.99
●	208	23	0.99
●	118	4	1
●	165	15	0.99
mass	0.0234	2 %	1

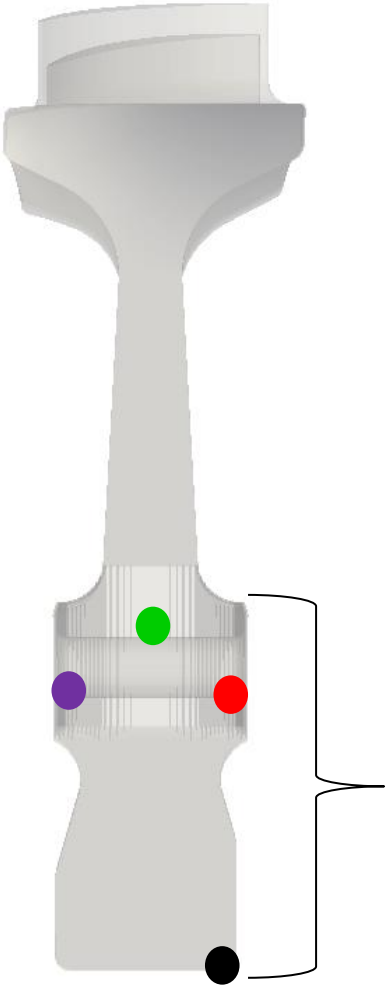
- 50000 shots MCS with variation range for system improvement

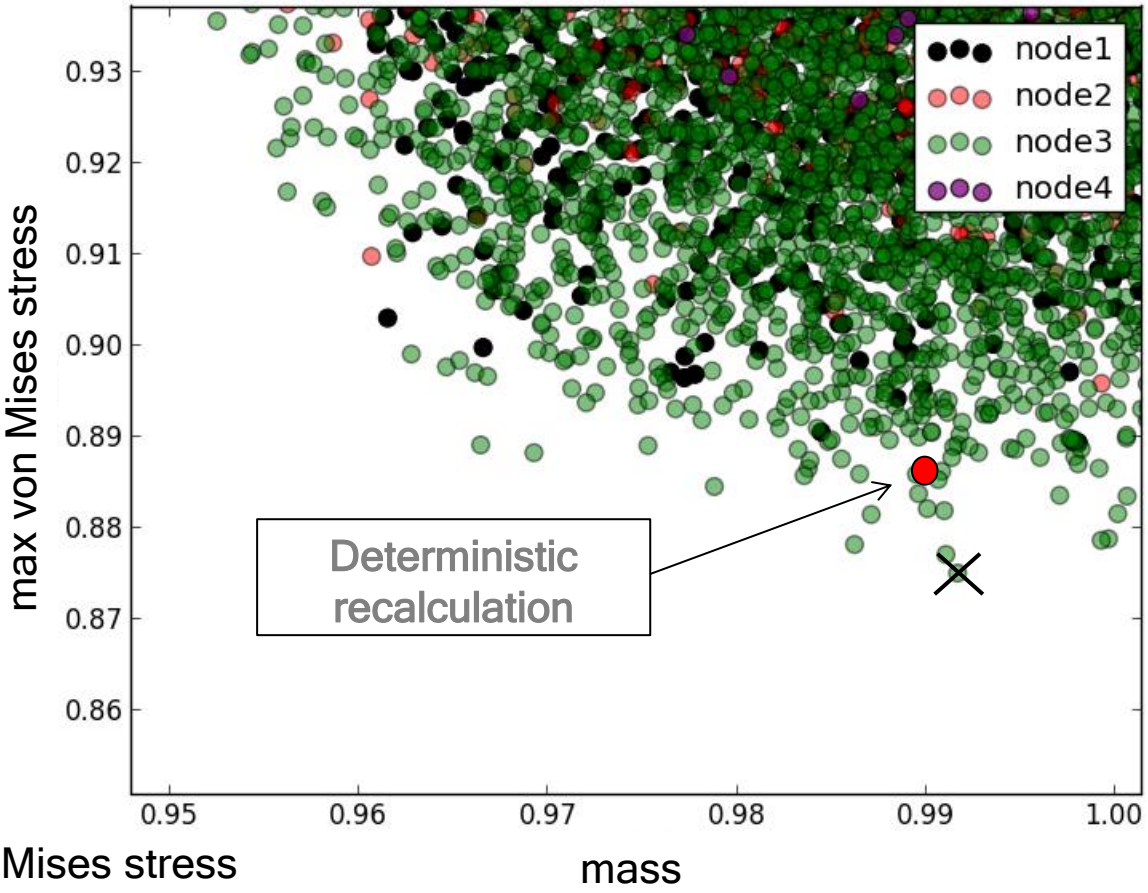




improvement by metamodel

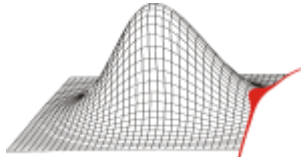
- 50000 shots MCS with variation range for system improvement

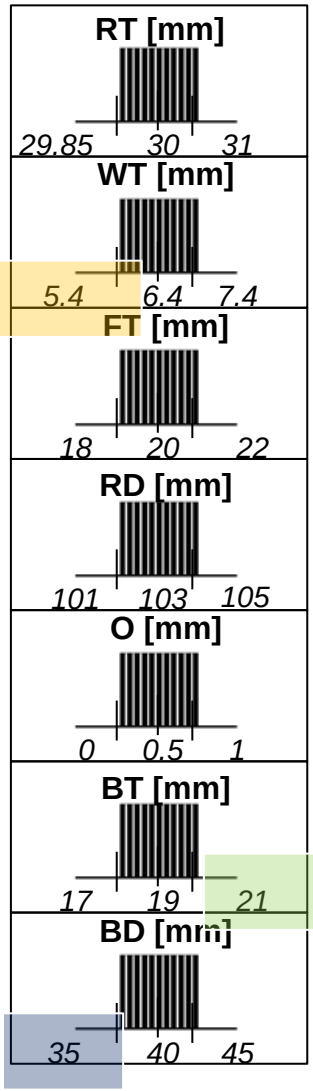




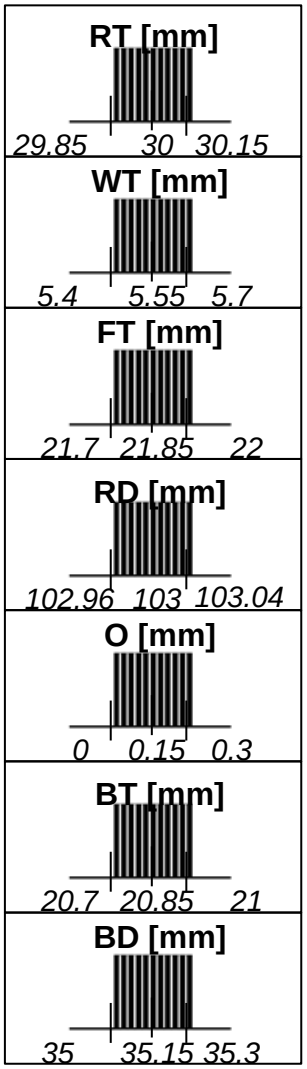
Max Mises stress

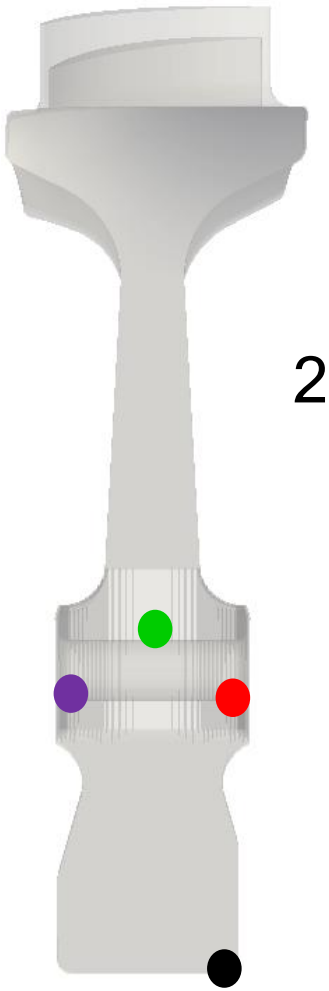
input values for design improvement

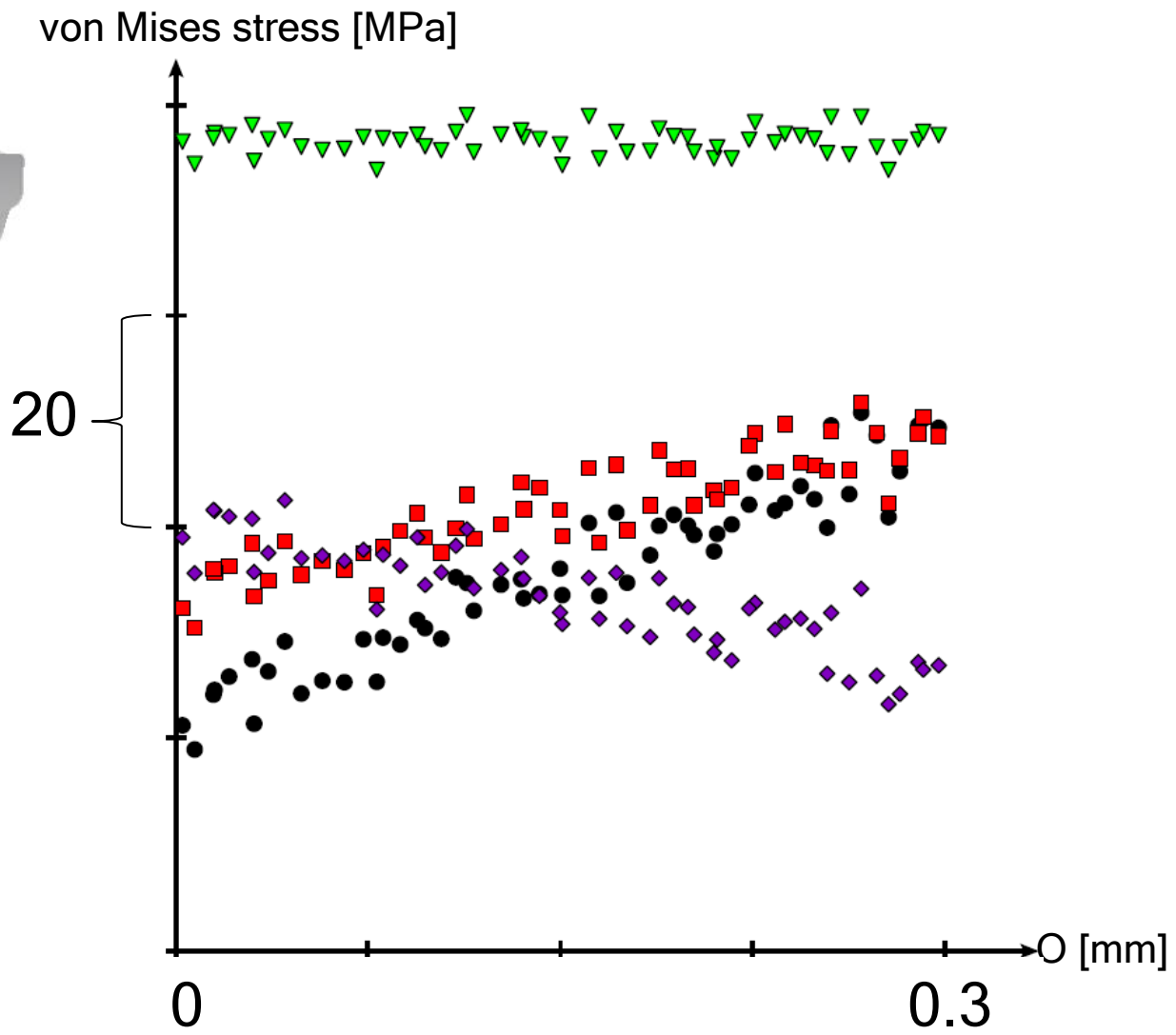




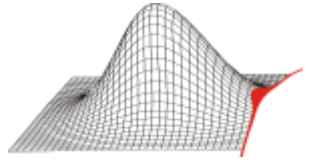
	Baseline	improved design by MCS Metamodell	improved design consider sensitivities
RT	30	30.1044	29.85
WT	6.4	5.42313	5.4
FT	20	21.606	22
RD	103	101.737	103
O	0.5	0.539213	0
BT	19	20.8614	21
BD	40	35.067	35
mass	1	0.9908	0.99167
Mises stress	1	0.8870	0.88468

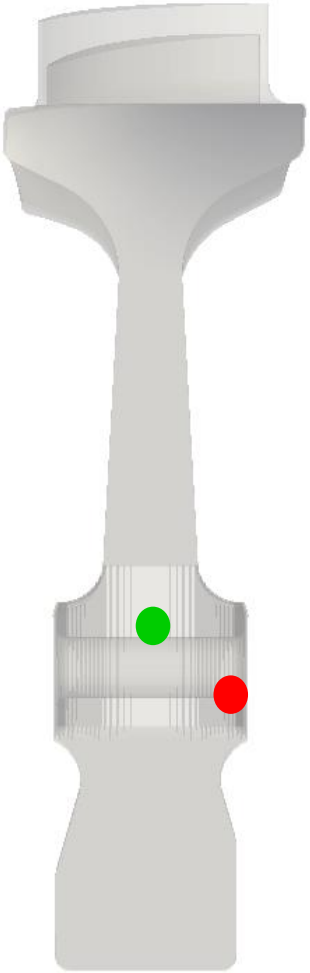

RT [mm]
29.85 30 30.15
WT [mm]
5.4 5.55 5.7
FT [mm]
21.7 21.85 22
RD [mm]
102.96 103 103.04
O [mm]
0 0.15 0.3
BT [mm]
20.7 20.85 21
BD [mm]
35 35.15 35.3

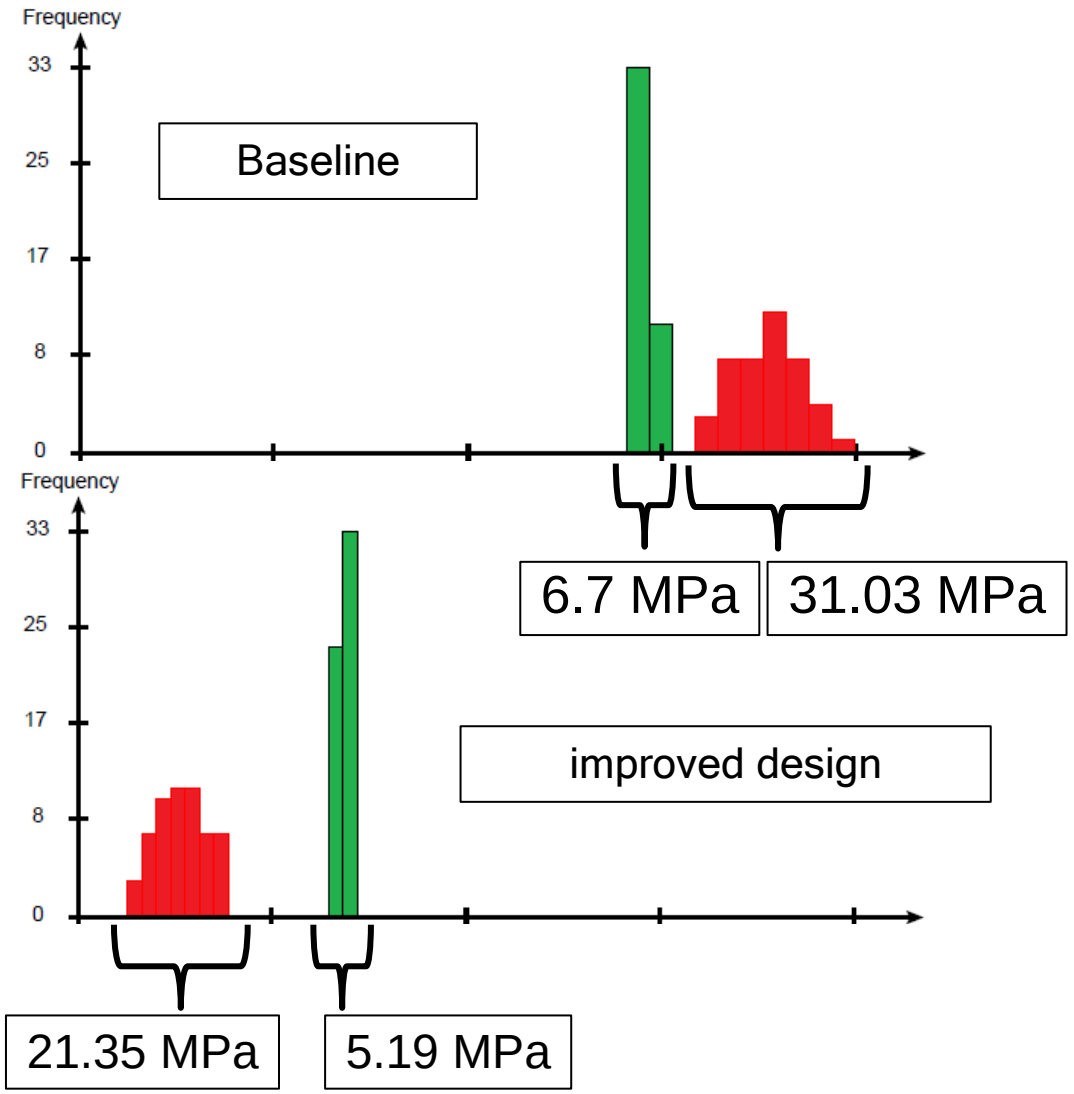



von Mises stress [MPa]
20
O [mm]
0
0.3

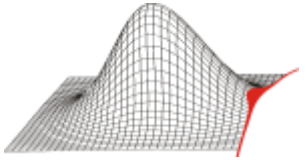
MCS manufacturing tolerances on improved design







summary



- implementation of a deterministic automated process chain
- demonstrate a system improvement with all important steps
  - analyse maximum von Mises stress of a base geometry regarding mean value and scatter
  - perform MCS with improvement parameter range
  - improvement of the base geometry with a metamodel
  - Checking the new improved geometry with manufacturing tolerances

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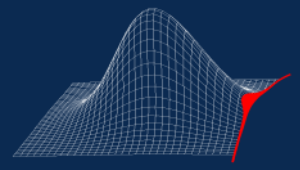

Thank you for your attention!

[1] Will, J.; Bucher, C.: *Statistische Maße für rechnerische Robustheitsbewertungen CAE gestützter Berechnungsmodelle.* Weimarer Optimierungs- und Stochastiktage 3.0, 2006.