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Ingenuity for life

Investigation of low cycle fatigue on large gas turbine casings under consideration of geometric tolerances

Untersuchung der Lebensdauer von Gasturbinengehäusen unter Berücksichtigung geometrischer Streuungen

Uwe Lohse Siemens AG Large Gas Turbines; Burkhard Voss Siemens AG Large Gas Turbines; Thorsten Lowitz Siemens AG Large Gas Turbines

Holger Schulze Spüntrup ITB Dortmund; Sebastian Wolff DYNARDO Austria

Where we are – Gas Turbine Locations & Joint Venture Partners

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The Siemens gas turbines portfolio: The right engine for every requirement

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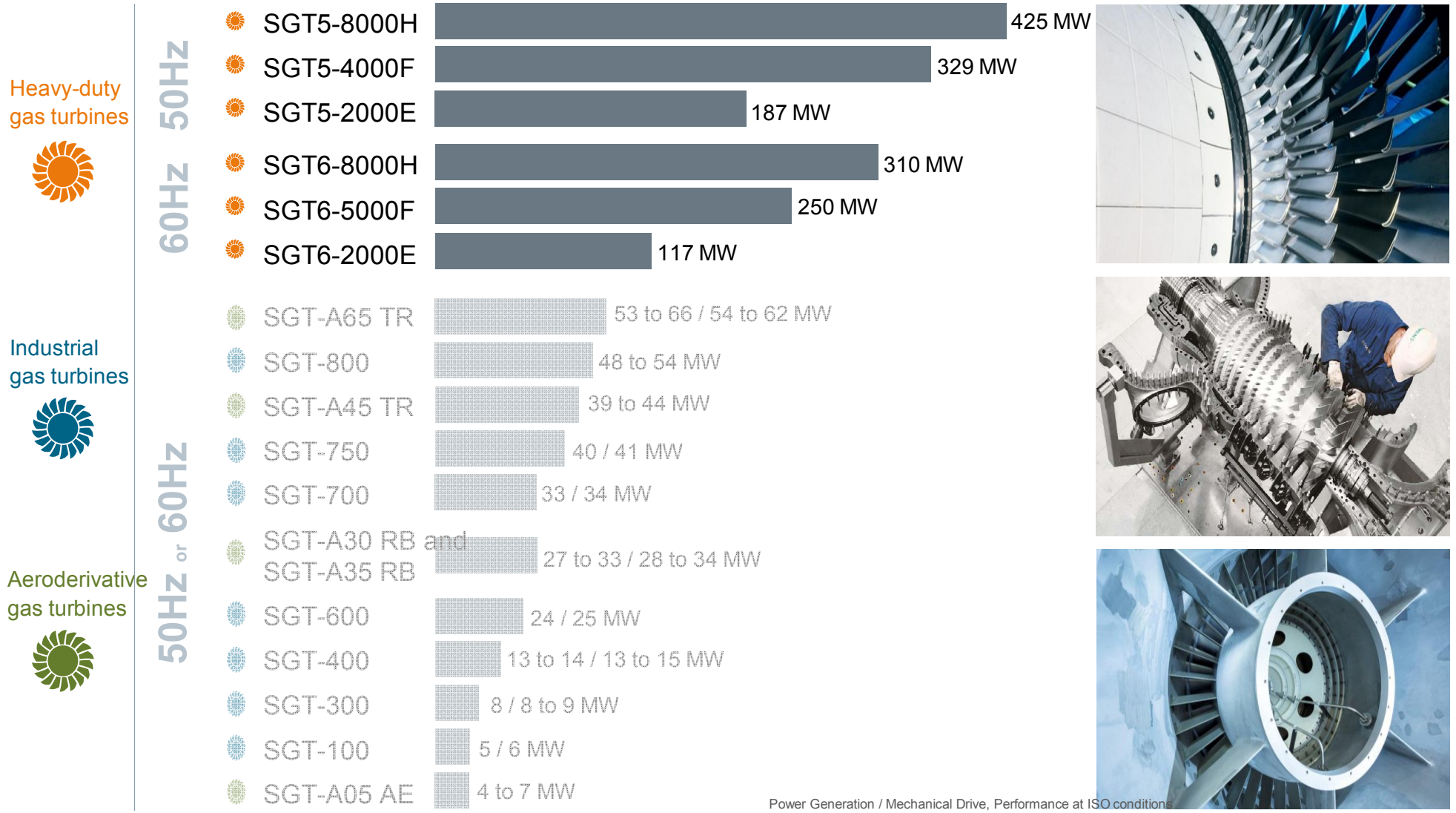
Technology Classification: ECC EAR99 AL:N US-Content: No



Power Generation / Mechanical Drive, Performance at ISO conditions

SGT5-8000H during assembly at Berlin plant

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Efficiency:

- GT > 40 %
- GUD 61 %

With district heating ~85 %

Power:

- GT 425 MW
- CCPP 630 MW

Weight: ~445 t

Length: ~12,6 m

Diameter: ~5,5 m

Fleet: > 74 units

SGT5-8000H Plant Lausward Duesseldorf
Press Release

SIEMENS

Düsseldorf. Siemens hat am 22. Januar 2016 das schlüsselfertig errichtete Gas- und Dampfturbinen (GuD)-Kraftwerk am Standort Lausward im Düsseldorfer Hafen an den Kunden und Betreiber Stadtwerke Düsseldorf AG übergeben. Das Kraftwerk wartet gleich mit drei neuen Rekorden im weltweiten Vergleich auf. In einer Testfahrt vor Abnahme wurde im Block „Fortuna“ eine maximale elektrische Leistung von 603,8 Megawatt (MW) erreicht, das ist eine neue Bestmarke für ein GuD-Kraftwerk dieser Auslegung. Gleichzeitig wurde ein Wirkungsgrad von rund 61,5 Prozent nachgewiesen – ein neuer Weltrekord.

Source:

WAZ

2016-01-28

Das neue Erdgaskraftwerk ist am Netz

Das Gas- und Dampfkraftwerk ist ein Meister der Wiederverwertung von Energie. Die Reibungsverluste, die bei der Umwandlung von Energie in Strom auftreten sind deshalb geringer als bei anderen Kraftwerken. Durch das Zusammenspiel mit Fernwärme erreicht das Kraftwerk einen Wirkungsgrad von 85 Prozent (bei Steinkohlekraftwerken liegt der Wert bei 45 Prozent). Dank umweltschonender Technik werden im ersten Betriebsjahr 600.000 Tonnen CO2 eingespart, im Jahr 2025 sollen es über eine Million Tonnen sein.

Source: RP 2016-01-29

Key thermodynamic values for bolting design

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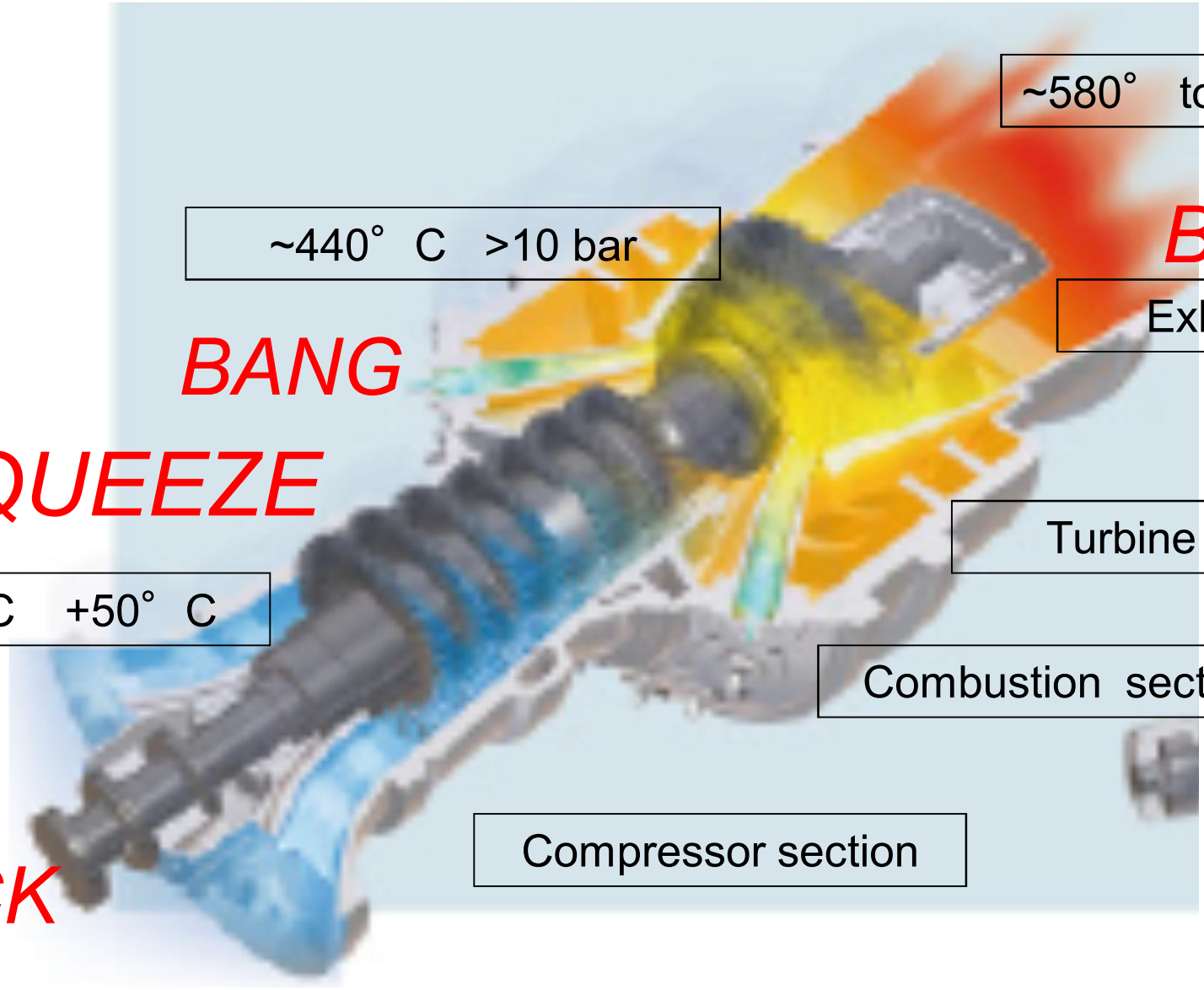

Motivation

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Customer requirements

- Effective
- Reliable
- Available
- Flexible
- Cost effective

Und was heißt das im Kraftwerk vor Ort?

- Wegfall der Gewinnmarge -> Sparen, sparen, sparen …
  - bei beinflussbaren Kosten wie Wartung, Reparatur
    - Instandhaltung bei Versagen und Verschleiß
    - Reparatur im Betrieb
    - Ausfall auch gewinnsteigernder Maßnahmen
  - Outsourcing bis hin zu Personalabbau
  - Flexible, vielseitig arbeitende Mitarbeiter
  - …

- Technische Herausforderungen
  - Neubewertung von Sicherheitsfaktoren und Lebenszeit
  - Hinterfragen von Betriebsanweisungen und –erfahrung
  - Ersatzbrennstoffe und Brennstoffband
  - Dehnung von Prüfintervallen
  - Neue technische Lösungen …

Die Energiewende und die Rolle fossiler Kraftwerke

Dr. Lars Wiese, E.ON Kraftwerker

Leibnitz Universität Hannover, Institut für Turbomaschinen und Fluid-Dynamik (TFD)
Ringvorlesung „Transformation des Energiesystems“ 23.04.2014

e·on

Pushing design closer to the limits to fulfill the customer requirements

Motivation

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With a classical deterministic approach it is difficult to fulfill the customer needs.

Safety factors for every impacted parameter used

- Material distribution
- Boundary condition
- Geometry variation

Probabilistic approach helps to fulfill the customer requirements

Only a probabilistic approach can consider the interaction of the impacted parameters

Effects on structural reliability / availability

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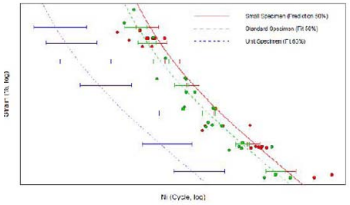
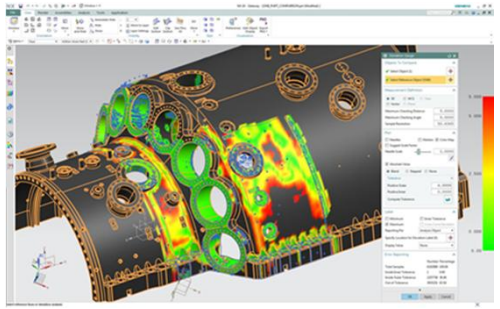
Material
Material scatter of properties and fatigue curve
Size effect also known as weakest link theory

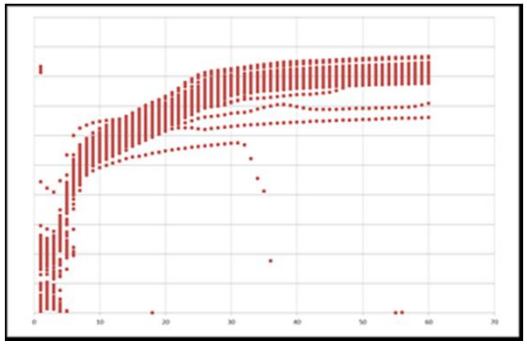


$$F_{\mathrm{Ni}}(n) = 1 - \exp\left(-\int_A \left(\frac{n}{N_{\mathrm{det}}}\right)^m dA\right)$$

Geometry
Manufacturing tolerances



Loading
Transient
Environment
Operation



This project deals only with the geometry's effect

The idea

Quantify geometry scatter and assess the effects on the structural behavior and design life

How to:

- 3D-Scan existing geometries
- Compare scanned and nominal geometry
- Get the deviation of the actual geometry from the nominal geometry
- Apply the deviation on a FE-Model
- Compare scanned and nominal geometry and their utilization

Repeat for many different deviated geometries to obtain representative data

Challenges on scanning

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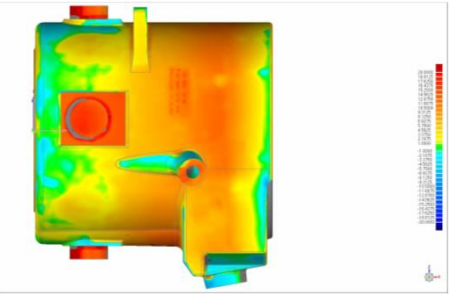
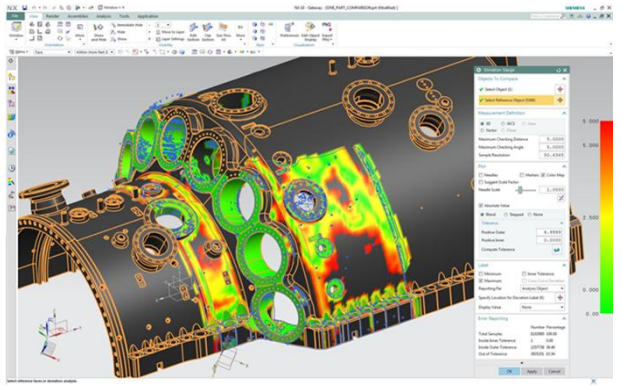
- Huge amount of nodes from 180° scan
  Nodes > 23.000.000
- Limited access for one scanner position due to the size of the object
- Limited time to scan in the production process
- Limited sample size due to long lead times
- Capability to repair and defeature scans required
  (actual with *GEOMAGIC* or *GOM* possible)





Improvement on scanning technic and time wishful for daily user

Impression of laser scan measurement

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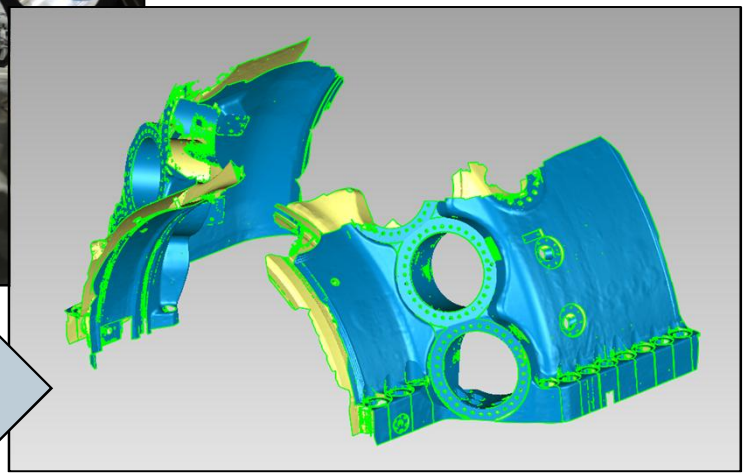

Photogrammetry system *GOM Tritop* in combination with the *GOM ATOS Triple Scan – Blue Light Scanner*.

Challenges on structure mechanic

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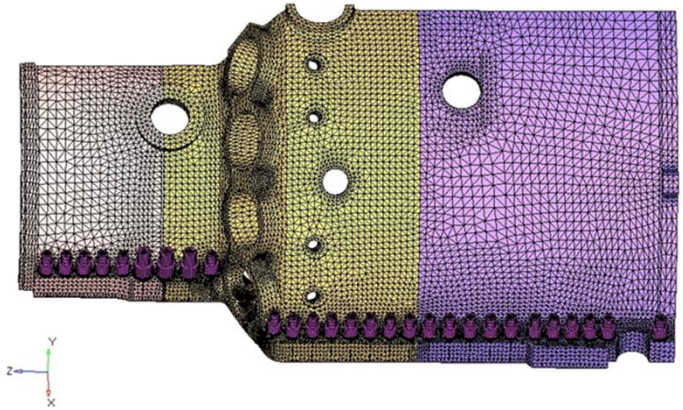
3D FEA including bolting contact and thermal transient required for realistic stresses for LCF assessment



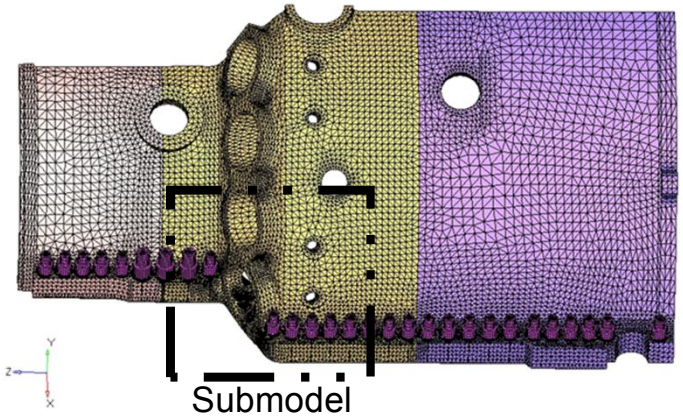
840.000 Nodes
380.000 Elements

>30 GB Disc space required
~ 3 Days on medium HPC hardware
⇒ Project time to run ~100 samples in robust analysis not feasible.

⇒ Disadvantage! Loss of global secondary membrane and bending effect on sub model.

Actual solution: use a sub model of the 90° FEA model

Challenges on structure mechanic



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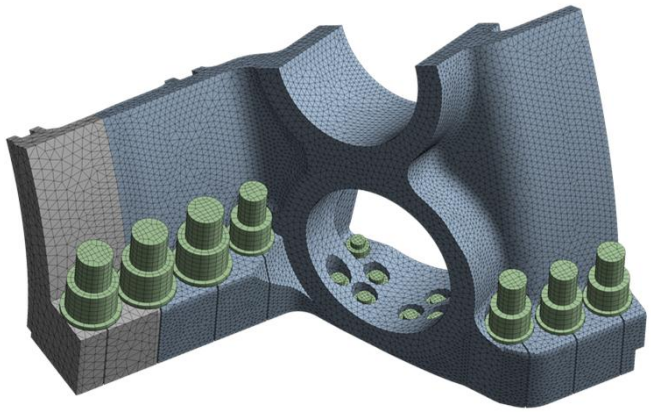
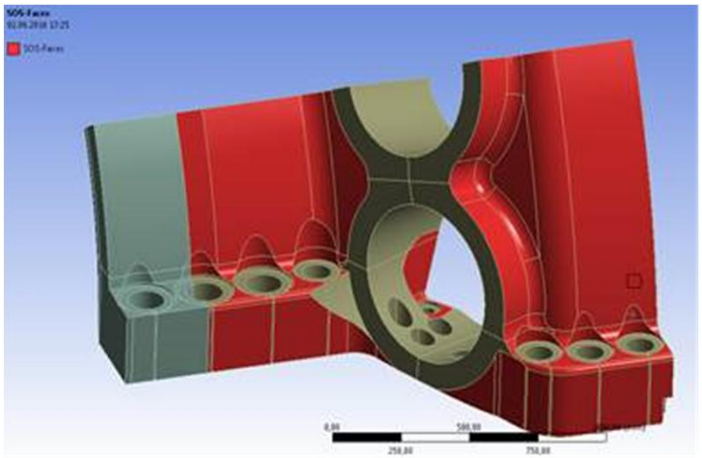


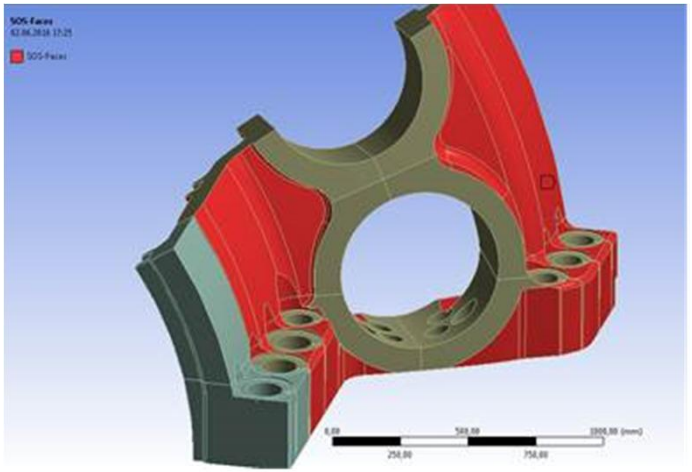
240.000 Nodes

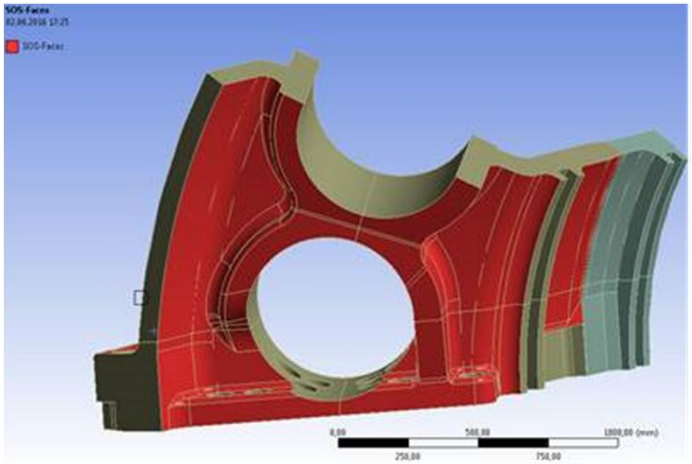
~7 GB Disc space per sample required
~ 90 min on medium HPC hardware
⇒ **~6 Days to run ~100 samples**

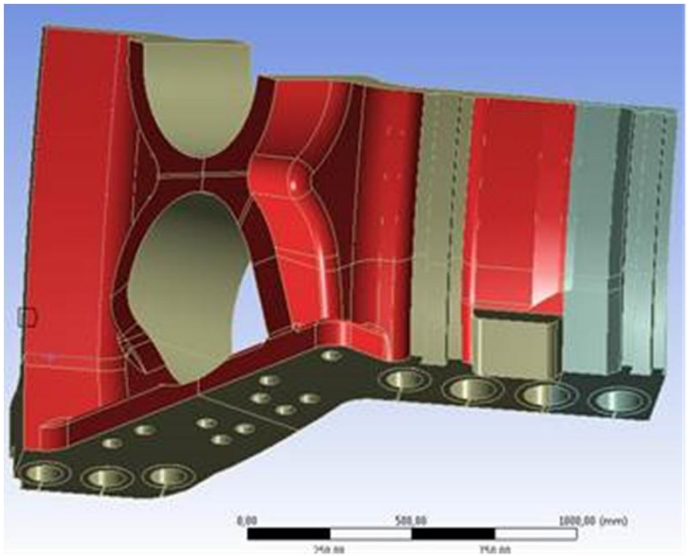
Trade-off between calculation time and result quality

Example of the sub Modell









Not machined surface.
Casting tolerance according ISO 8062

Statistics on Structures – How it works

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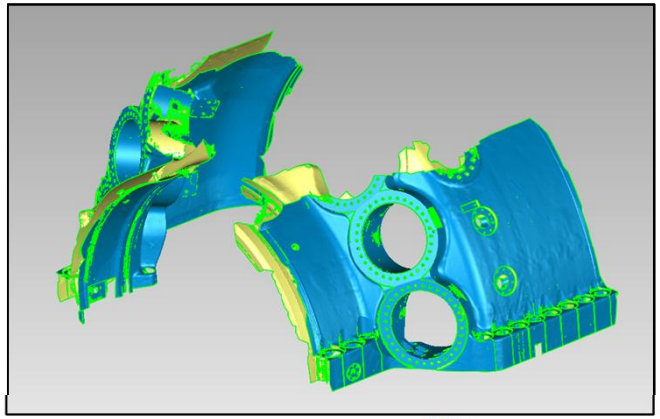
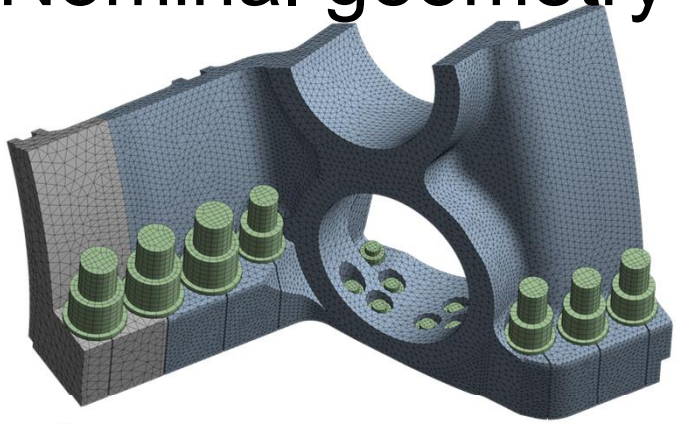
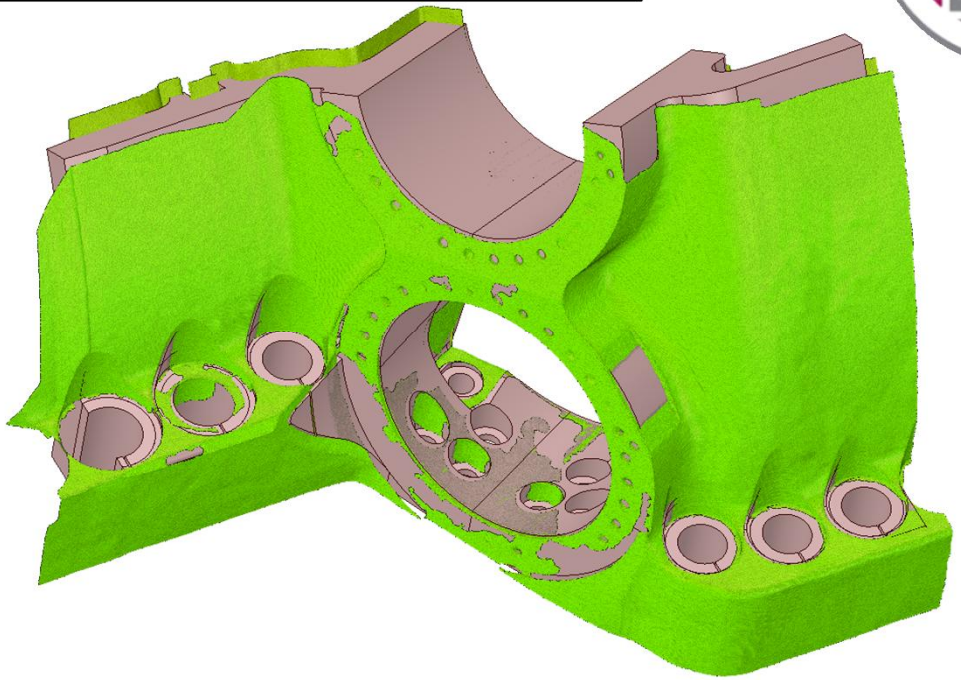
Scan

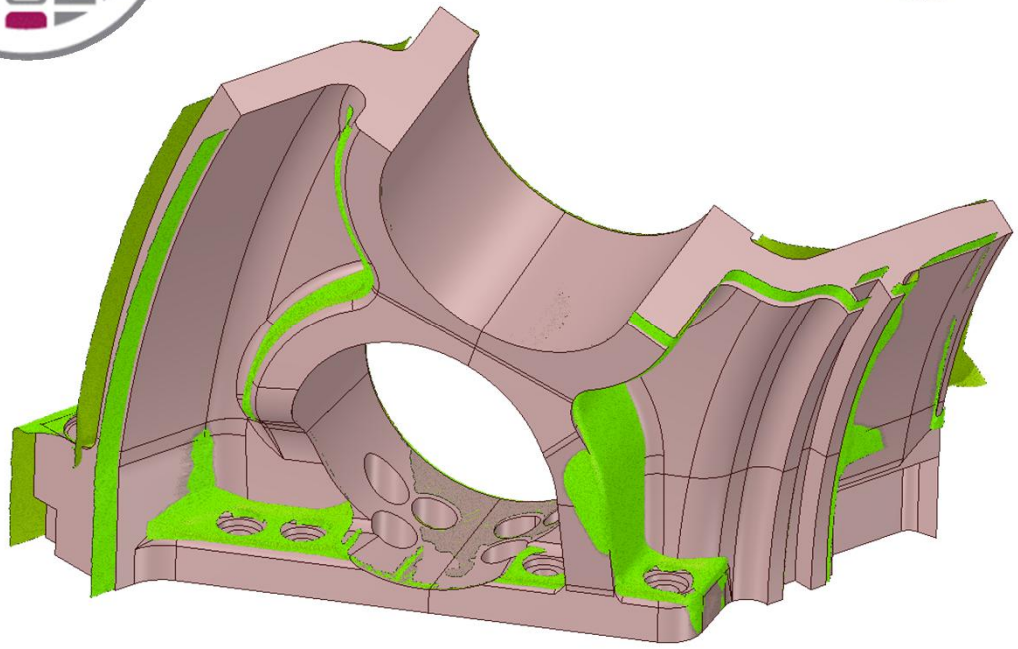


Statistics on Structures
(SoS)

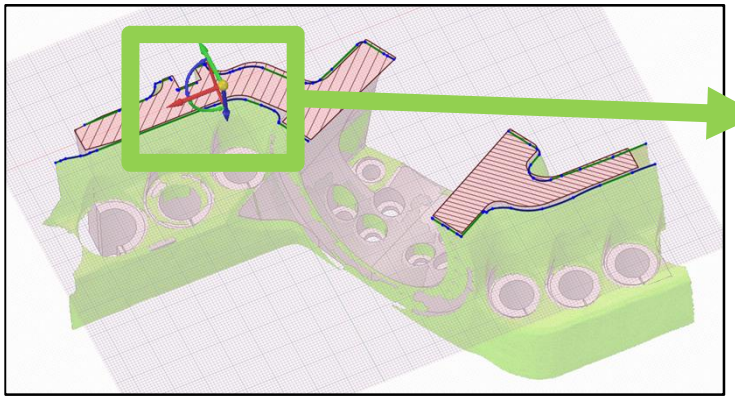
Nominal geometry

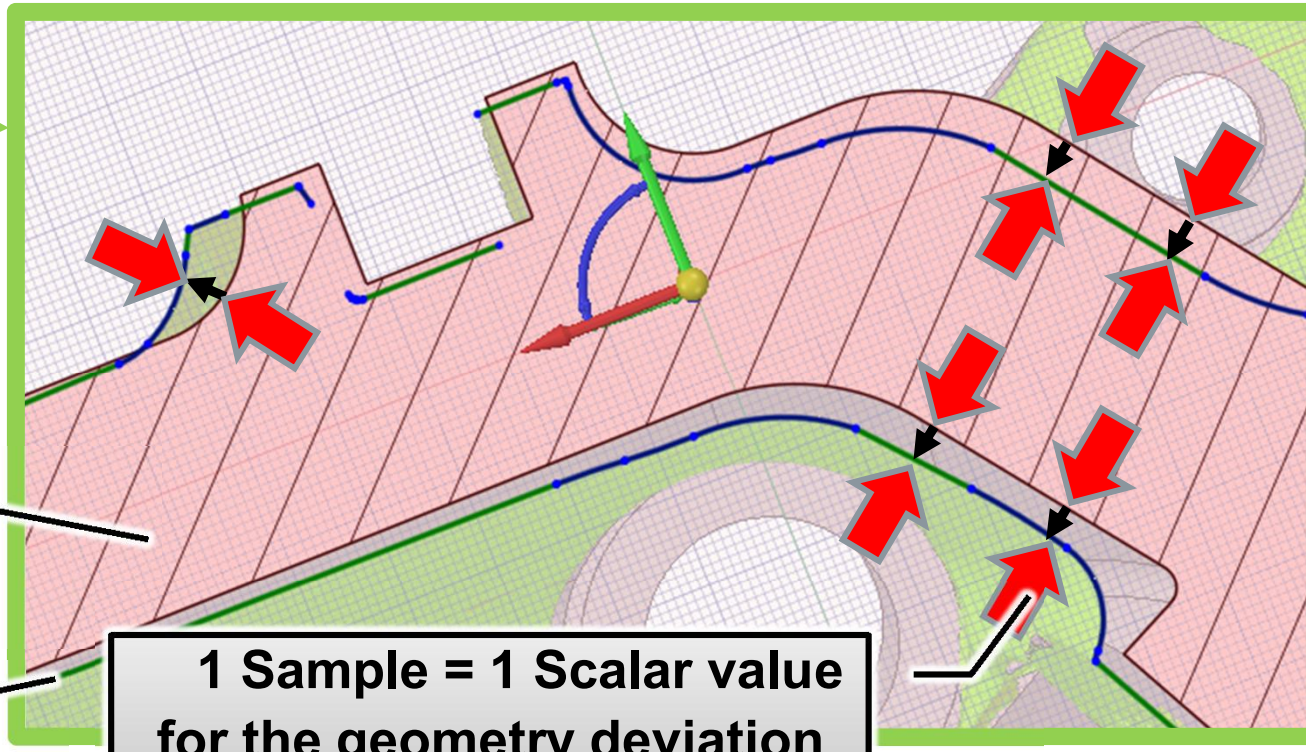




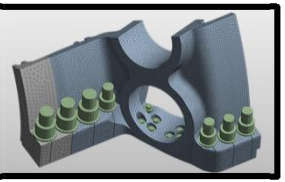


Statistics on Structures – How it works

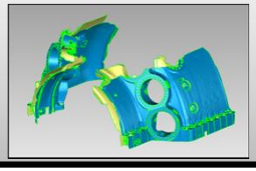




FE-Modell



Scan



1 Sample = 1 Scalar value for the geometry deviation per node and per scan

Example of scanning results based on 8 samples

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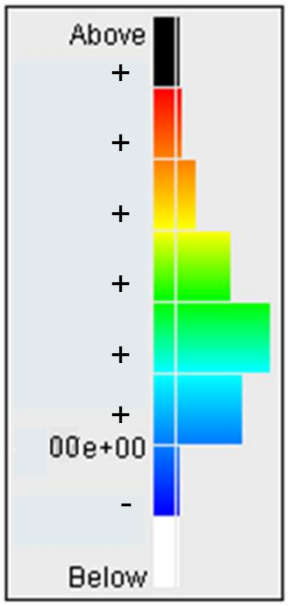
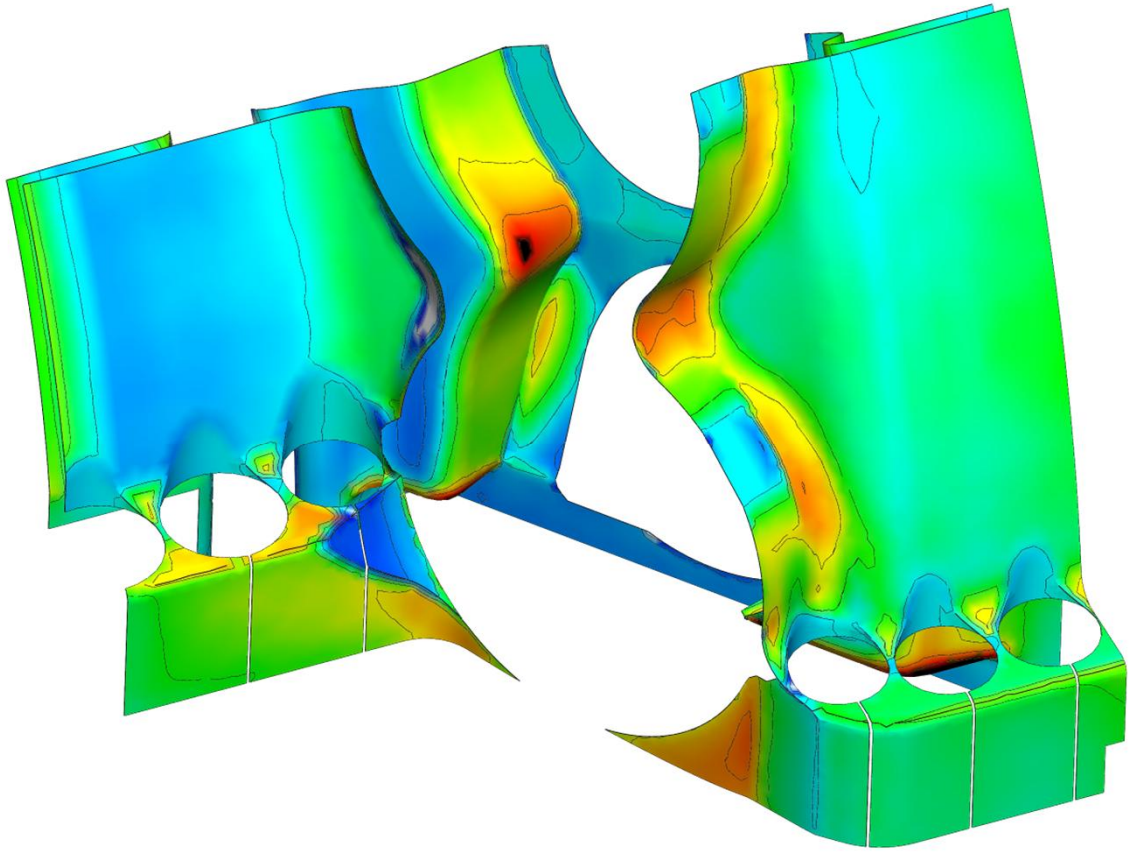
Mean deviation





Measured perpendicular to the surface coordinate; Normal vector direction

Example of scanning results based on 8 samples

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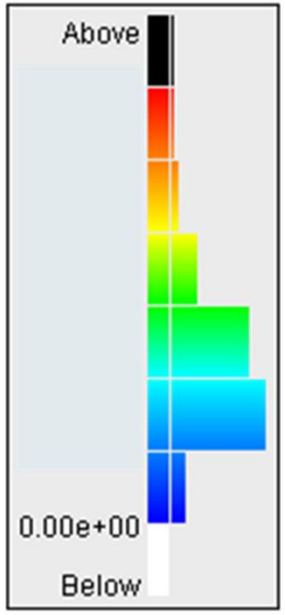
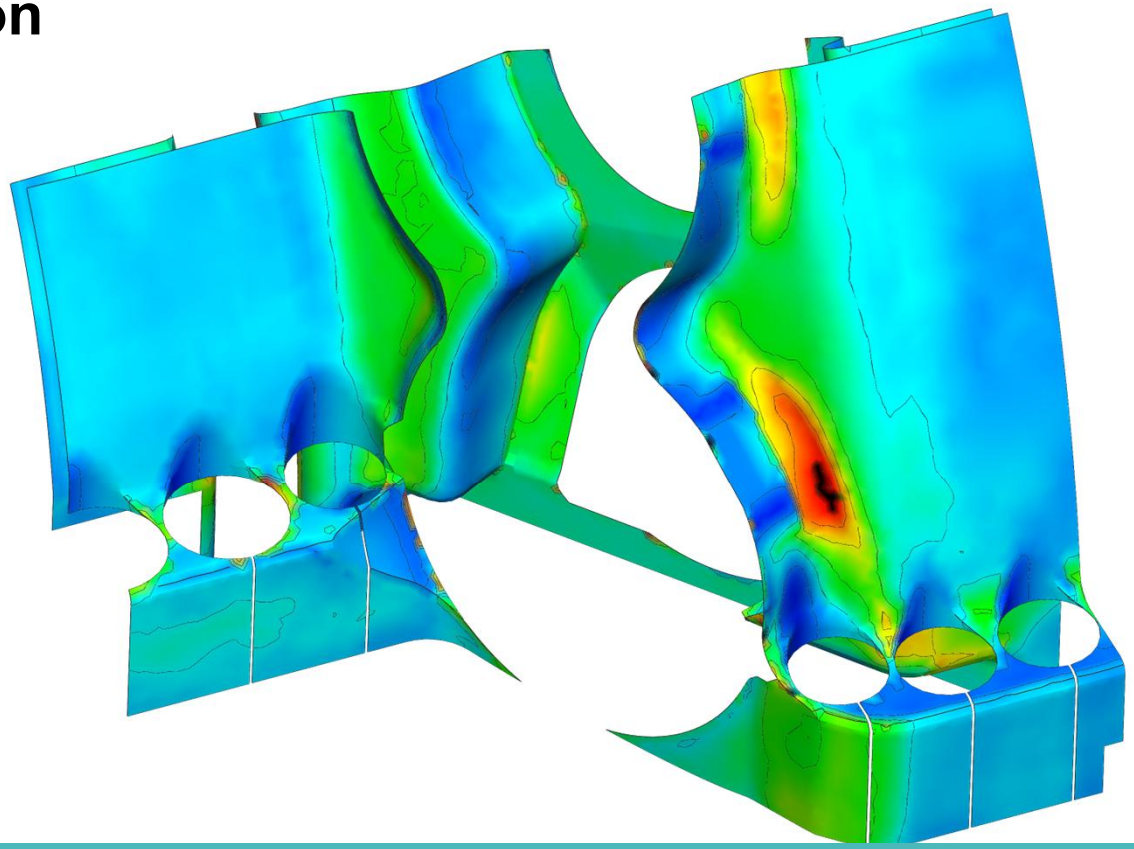
Standard deviation





Basic statistic quantities can already be obtained

Example of scanning results based on 8 samples

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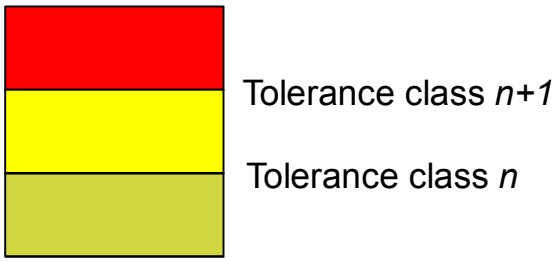
Casting tolerances according ISO 8062-3

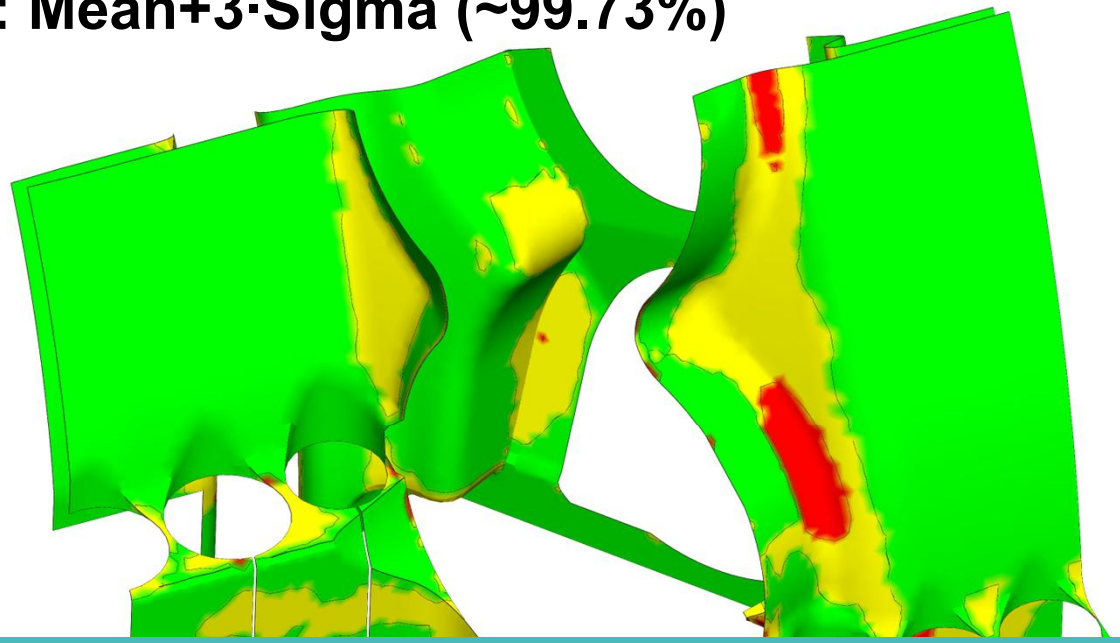
>4000	≤ 6300									7,0	10,0	14,0	20,0	28,0	35,0	44,0	56,0
>6300	≤ 10000										11,0	16,0	23,0	32,0	40,0	50,0	64,0

Absolute deviation: Mean+3·Sigma (~99.73%)



Tolerance class *n+1*

Tolerance class *n*



Basic quantities show critical locations for quality checks

Method to work with limited sample size

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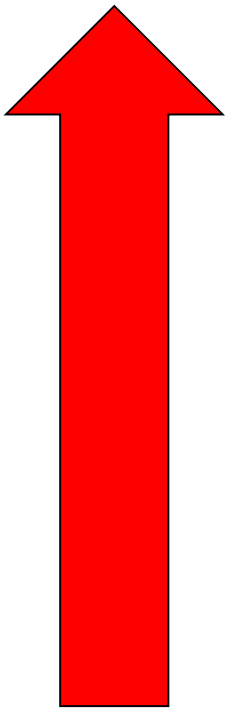
Empiric random field > 100 scans

Semi synthetic field ~5 scans used to calculate mean value and standard deviation. Field simulated at random with mean an STDDEV from small number of scans

Full synthetic Random simulations based on experiences from other projects or local CTQ records (critical to quality): CTQ are standard of the quality process but only local and can‘t include the full field information.

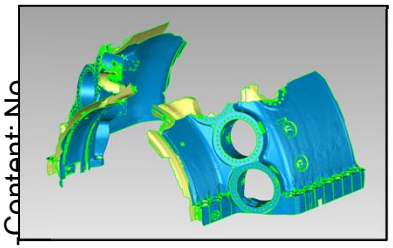


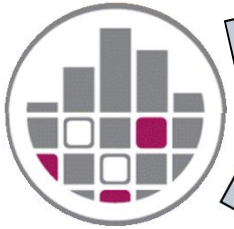
Decreased effort to collect data

Decreased effort to retrieve high quality results

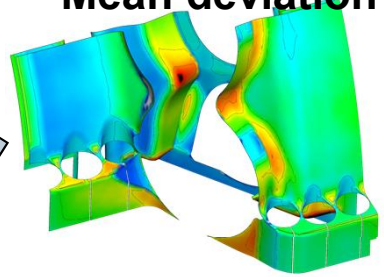
Compromise between effort to collect data and the result quality needs to be discussed between the involved parties before the project starts.

Semi synthetic field





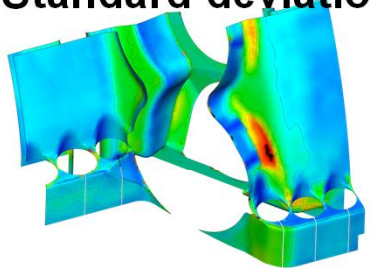
Mean deviation



=

μ
mean value

Standard deviation



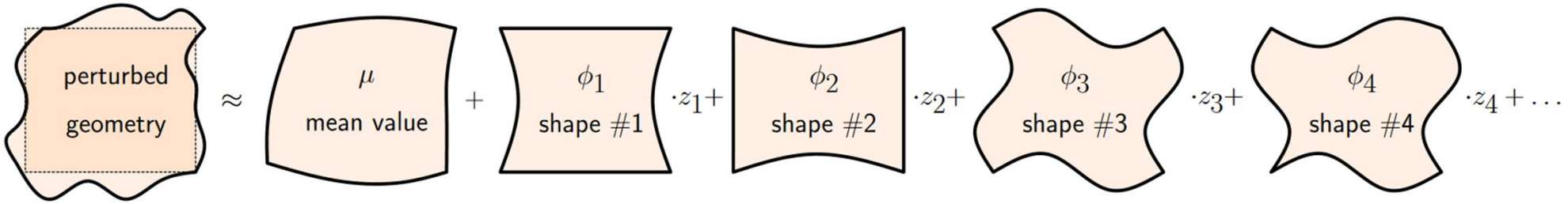
Spectral decomposition

ϕ_1
shape #1

ϕ_2
shape #2

ϕ_3
shape #3

Linear combination of mean value and randomly scaled scatter shapes



Semi synthetic field

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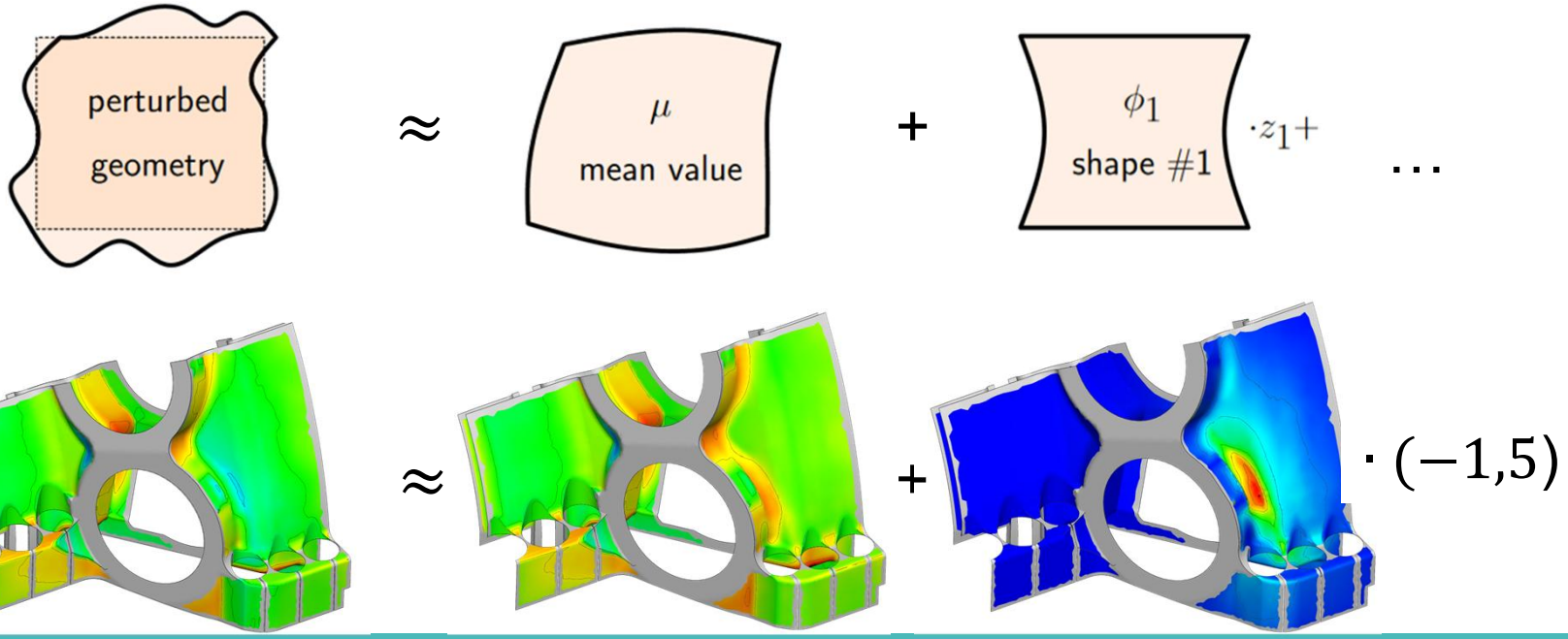
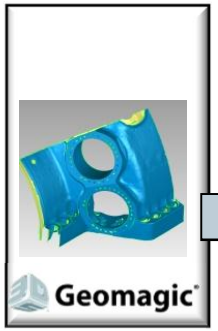
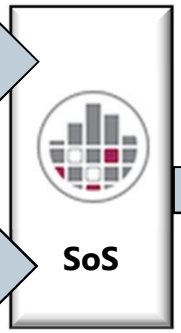
Linear combination of mean value and randomly scaled scatter shapes

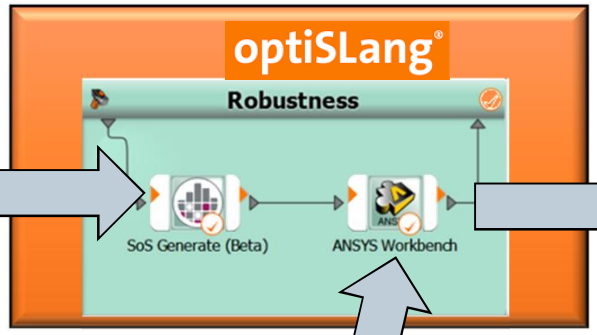


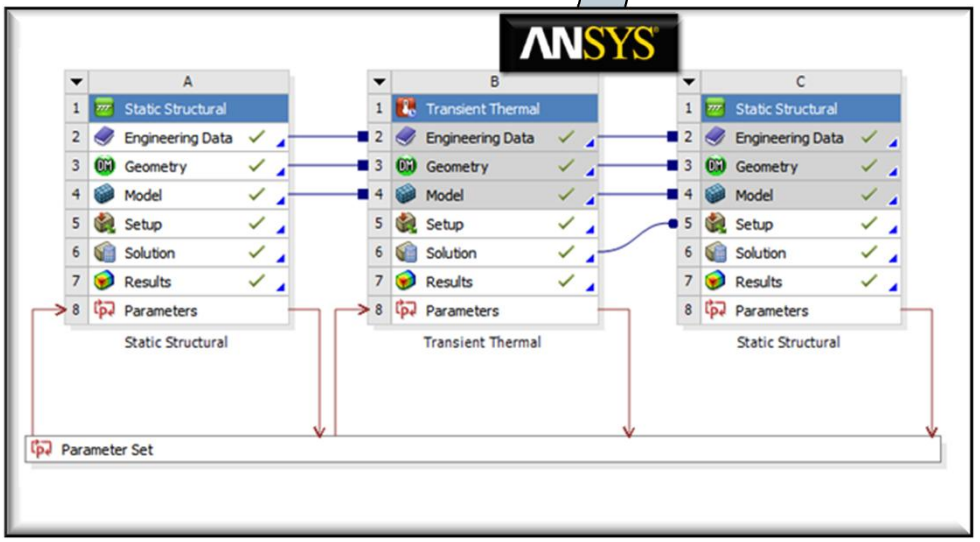
It‘s possible to create an arbitrary amount of different geometry variations

Workflow / Theory



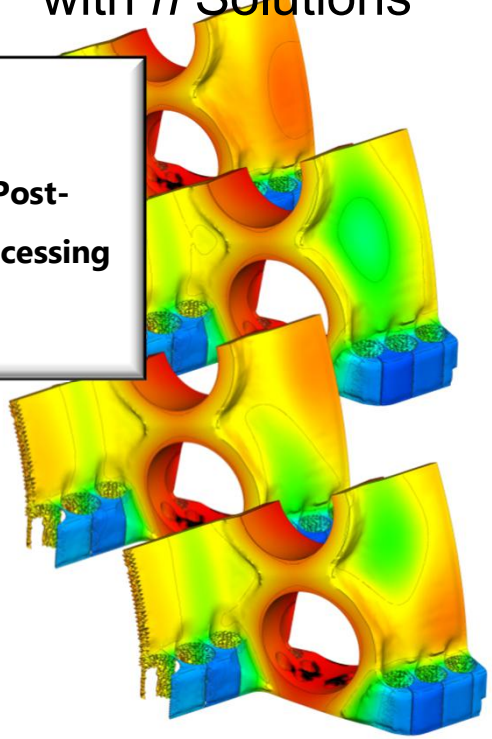




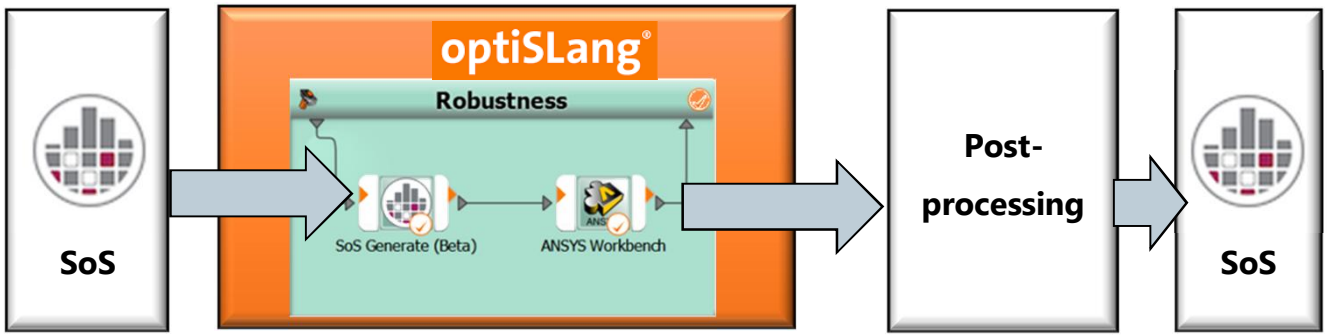


Post-processing

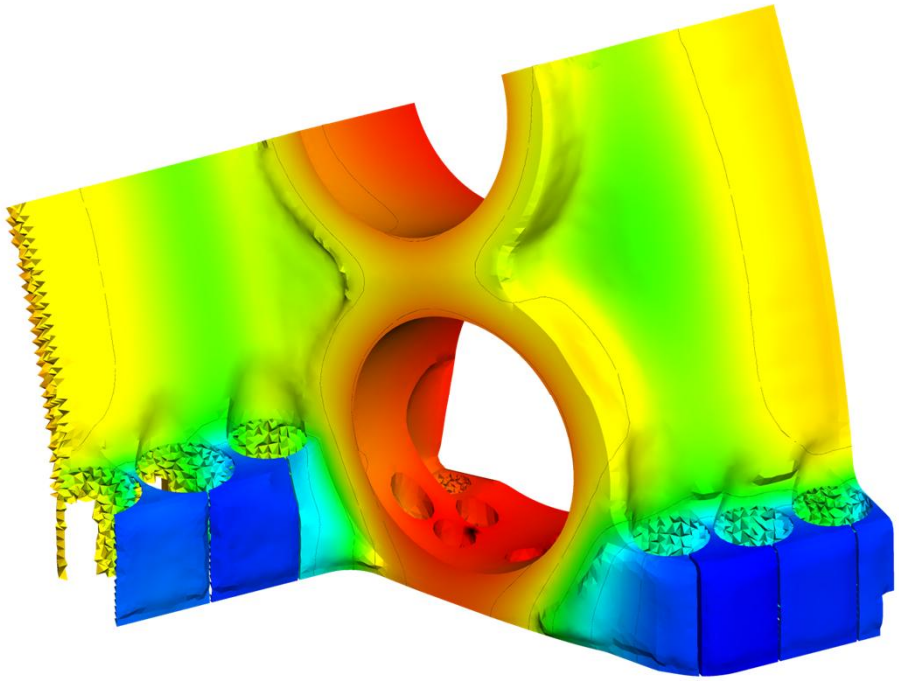
n Designpoints with *n* Solutions



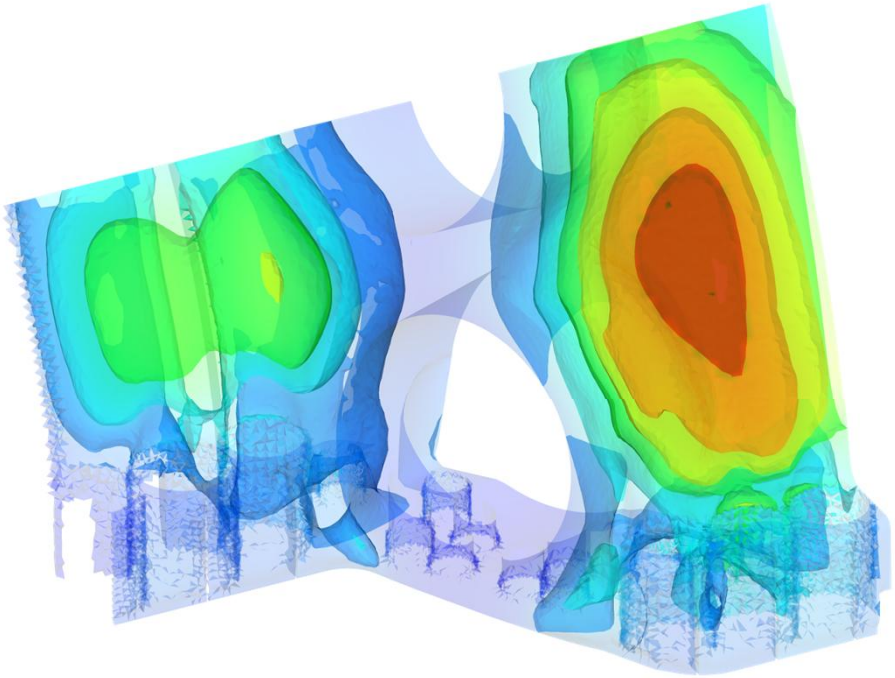
Workflow / Theory



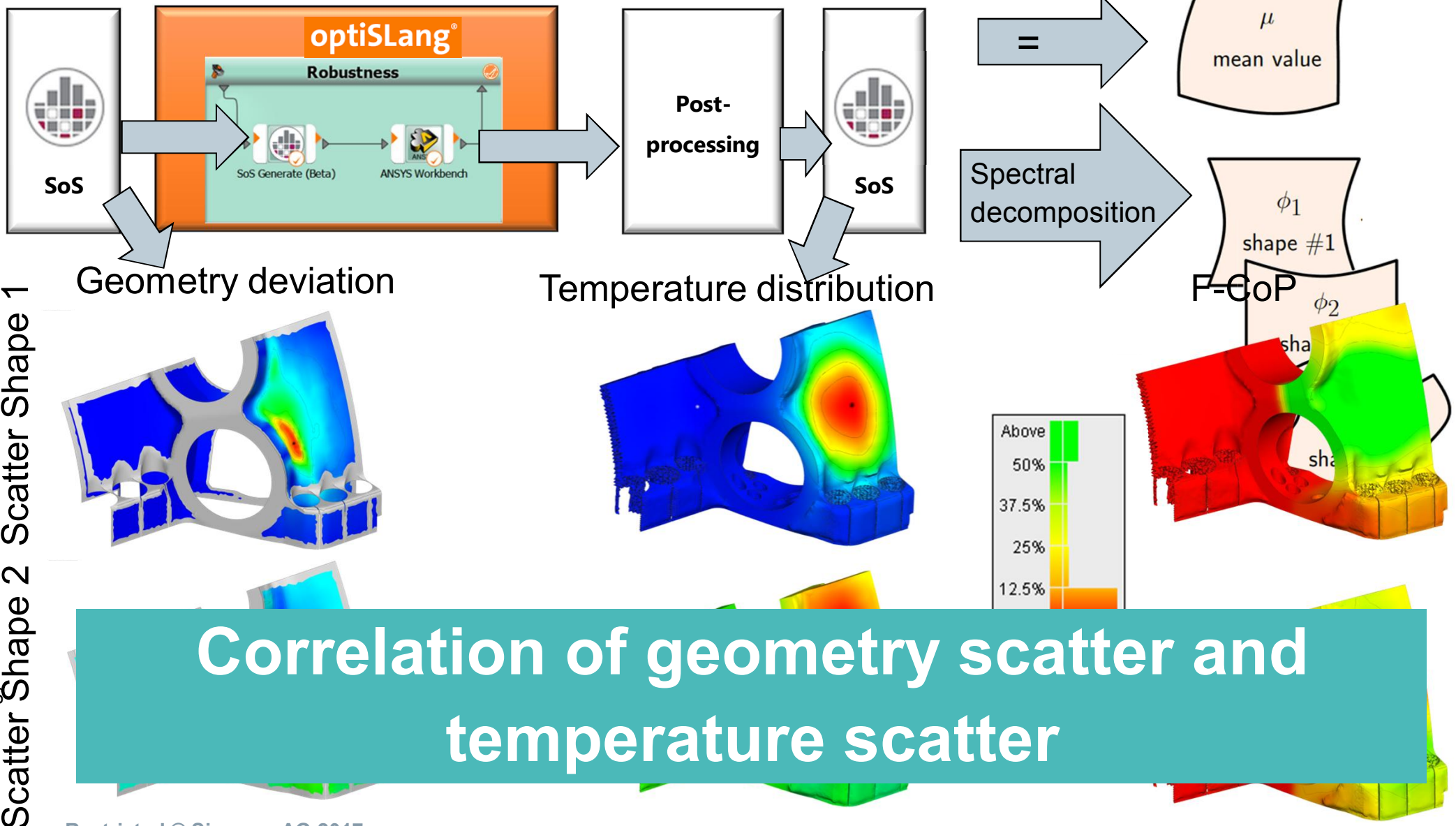
Mean temperature



Standard deviation of temperature

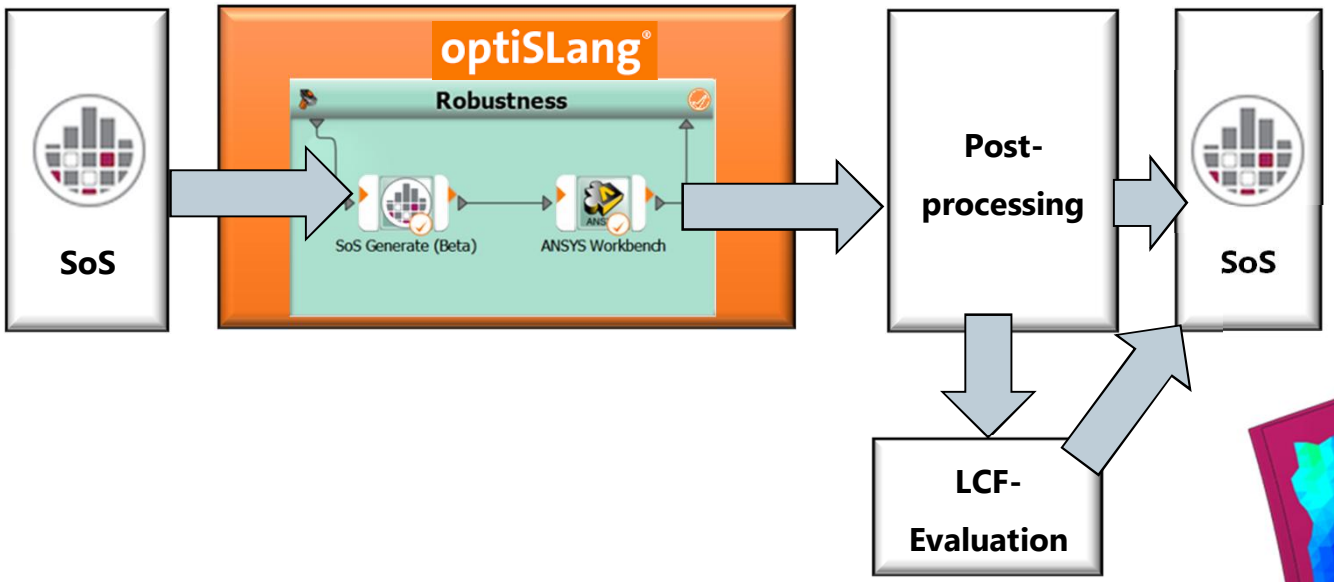


Workflow / Theory

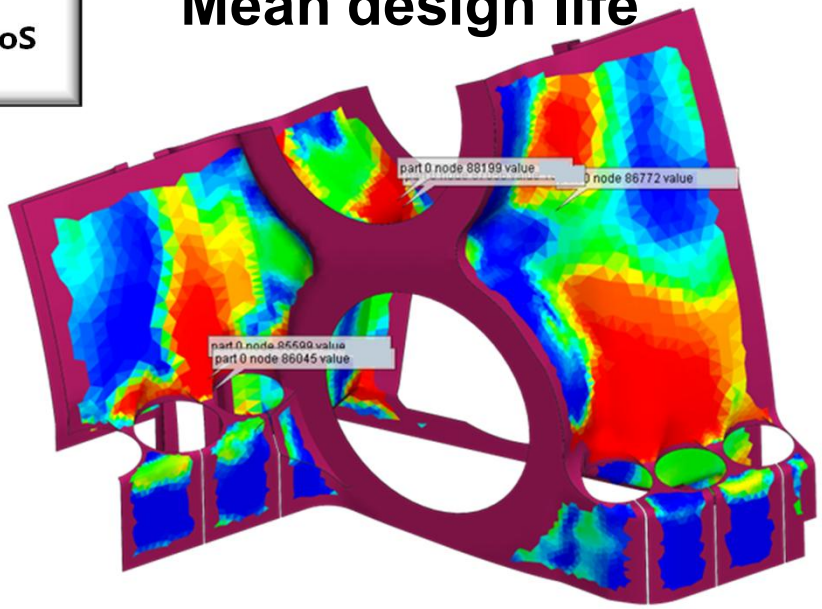


Correlation of geometry scatter and temperature scatter

Workflow / Theory



Mean design life



Similarly, the workflow allows correlation of geometry scatter and design life scatter

Design Life

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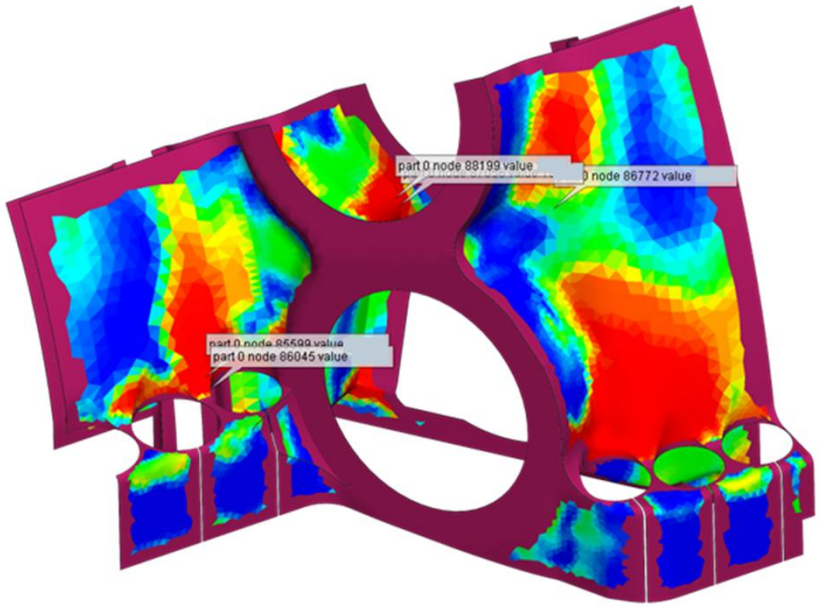
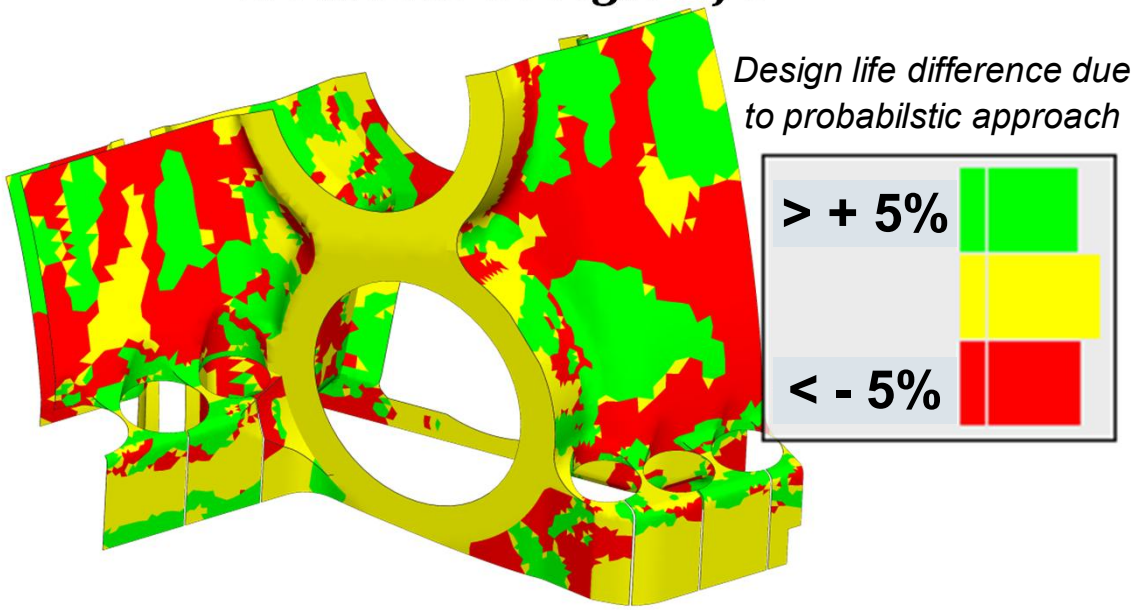
Mean design life



$$\frac{Mean\ design\ life\ -\ Nominal\ design\ life}{Nominal\ design\ life}$$



Considering geometry scatter shows increased as well as decreased design life → Assessment of nominal geometry is globally a good approach

Design Life

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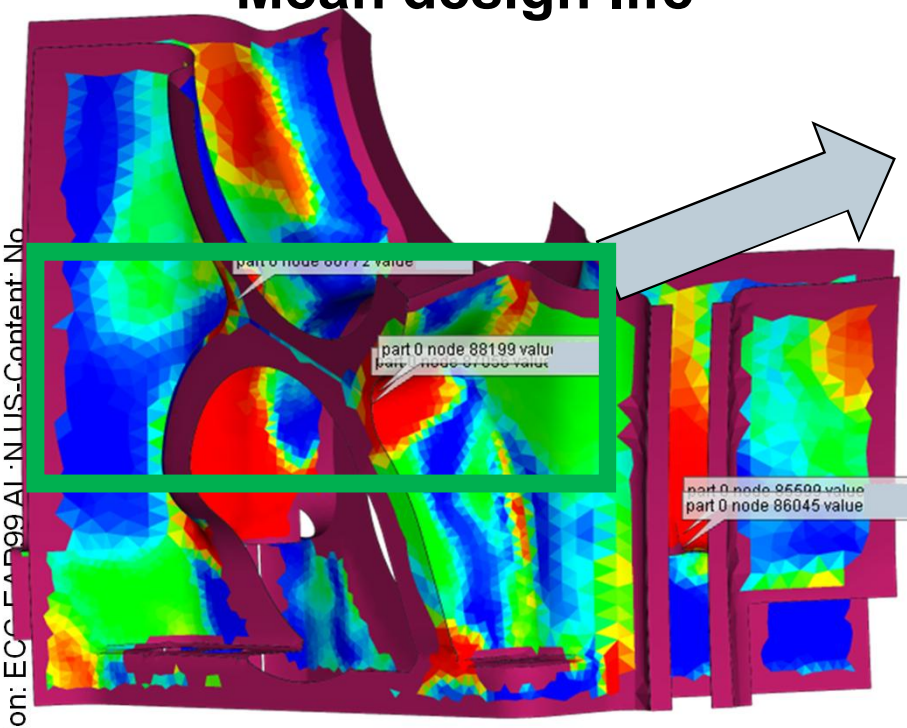
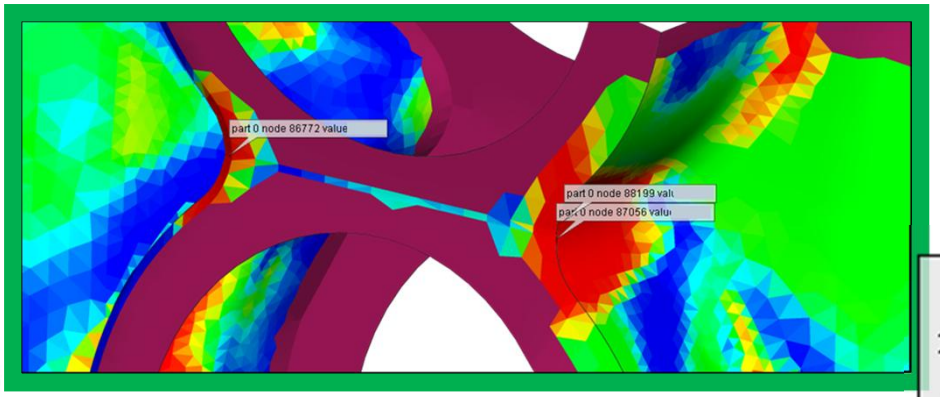
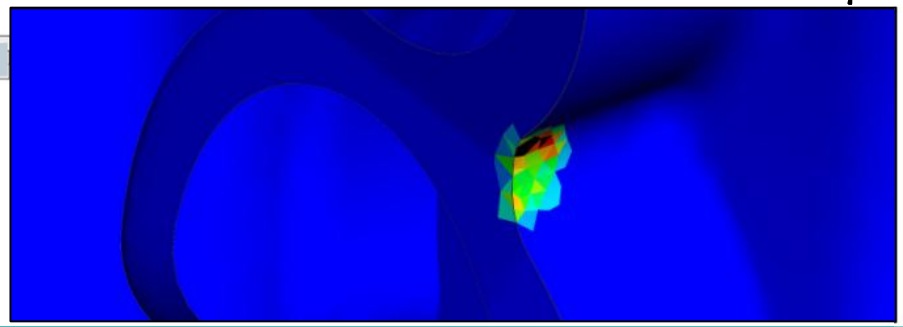
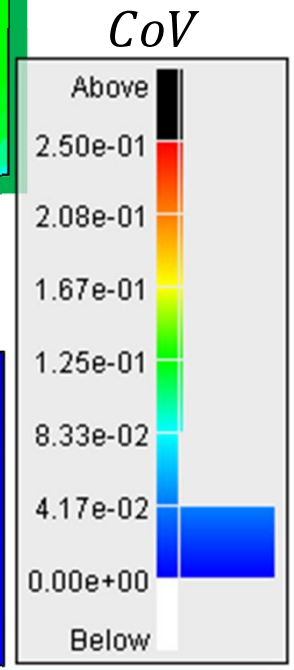
Mean design life





$$Coefficient\ of\ Variation\colon\ CoV = \frac{\sigma}{\mu}$$

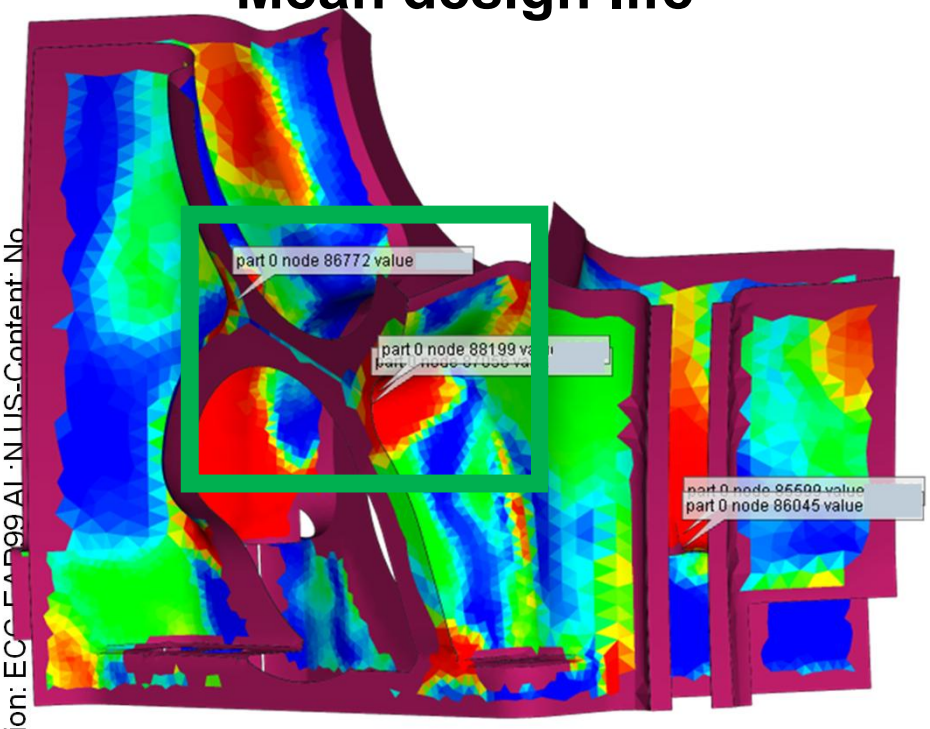




However, local scatter of design life can only be considered by probabilistic approach and may lead to different highly utilized locations

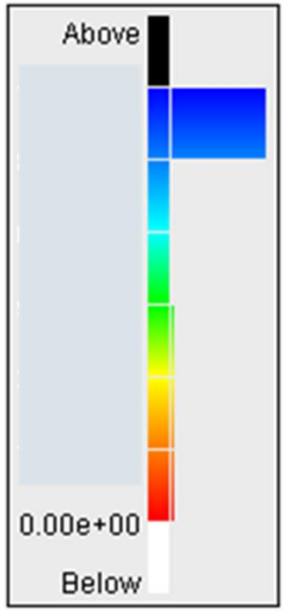
Design Life

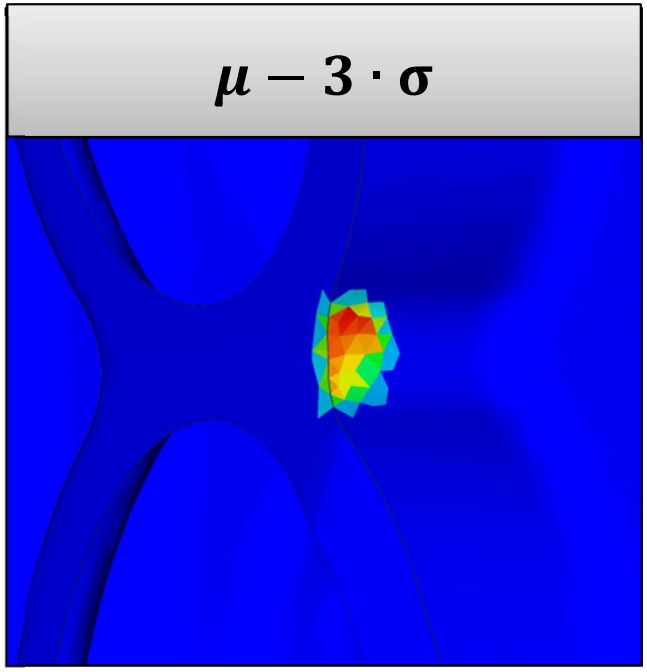
Mean design life



-3σ Design life

Minimal values for 99.7% of real geometries





However, local scatter of design life can only be considered by probabilistic approach and may lead to different highly utilized locations

Summary

- Synthetic random fields allow probabilistic assessment of structures with few available scans
- Software allows correlation of geometry scatter and result scatter
- Correlation of input and output allows identification of locations of uncritical geometry scatter with respect to design life. Tolerances can be adjusted accordingly.
- Easy statistical evaluation of the results plotted directly on the model in SoS
- Due to consideration of geometry scatter according safety factors may be adjusted
- Still some work to do...
  - Increase of sample size
  - Automatization of process
  - ...

Contact and Acknowledgement

Uwe Lohse Uwe.lohse@siemens.com
Burkhard Voss Burkhard.voss@sienens.com
Thorsten Lowitz Thorsten.lowitz@siemens.com
Sebastian Wolff sebastian.wolff@dynardo.at
Holger Schulze Spüntrup Holger.Schulze-Spuentrup@itb-fem.de

The presentation is based on the master thesis of Holger Schulze Spüntrup at Fachhochschule Dortmund, University of Applied Sciences
Referent Prof. Marius Geller, Fachhochschule Dortmund
Co-referent Sebastian Wolff, DYNARDO Austria GmbH
Technical support Dr. Frank Bremer

Ingenieurgesellschaft für technische Berechnungen mbH
Europaplatz 7, 44269 Dortmund
Tel.: +49 (0)231 94 53 65 - 21
Fax: +49 (0)231 94 53 65 - 11
Geschäftsführer: Dr. Frank Brehmer
Handelsregister Dortmund: HRB 16440

www.itb-fem.de

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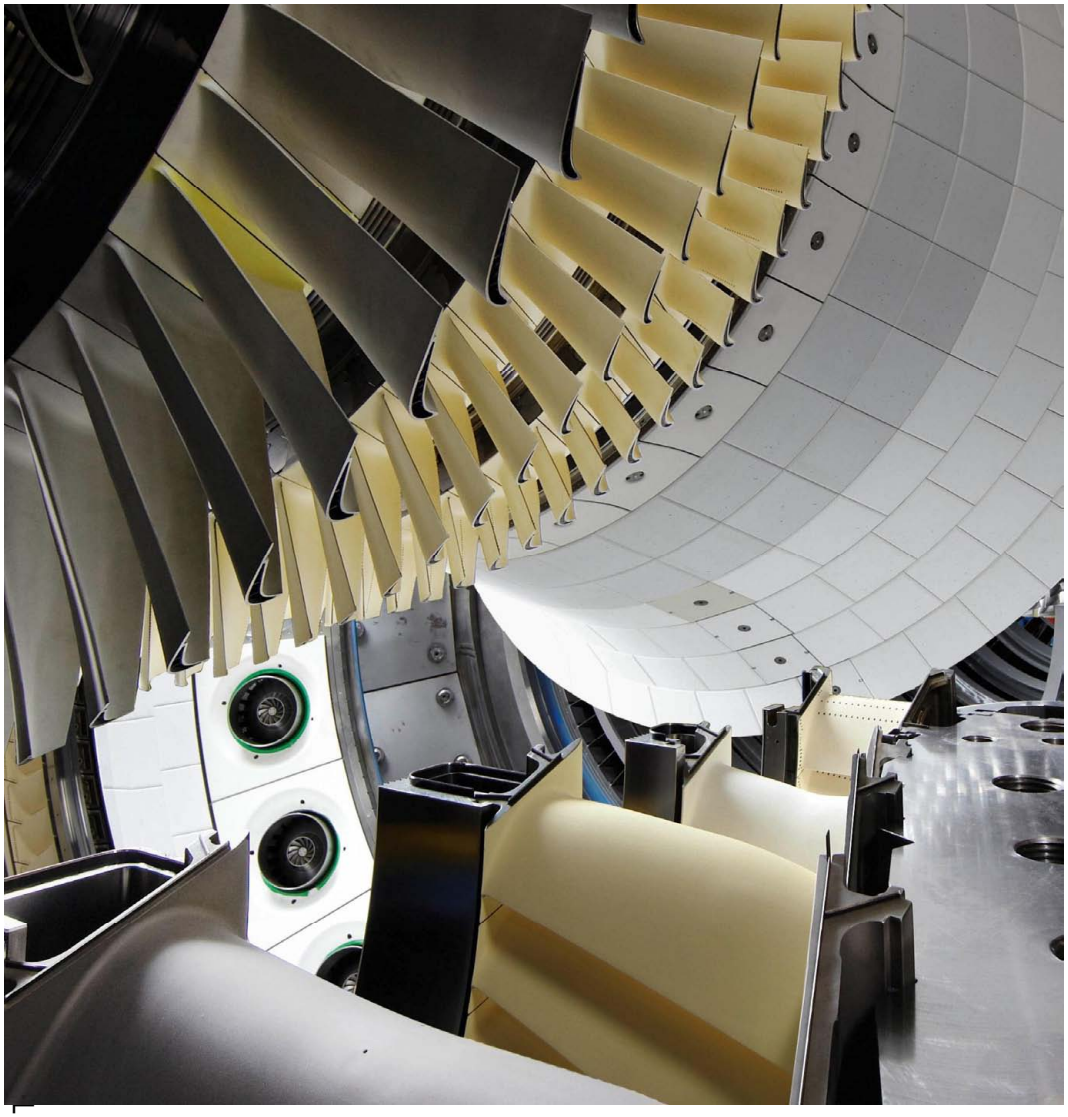

Thanks for your attention!

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