

Ansys

WOST

CONFERENCE

Recent Developments of Field Meta Models

June, 17th 2021

Sebastian Wolff

Director R&D optiSLang

Ansys

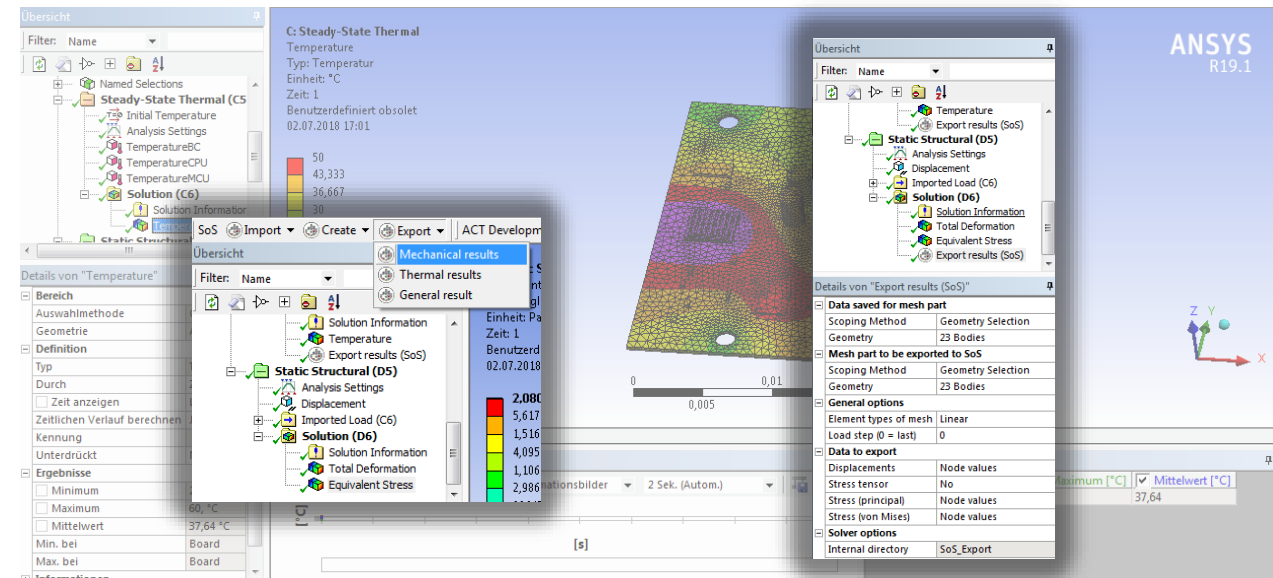
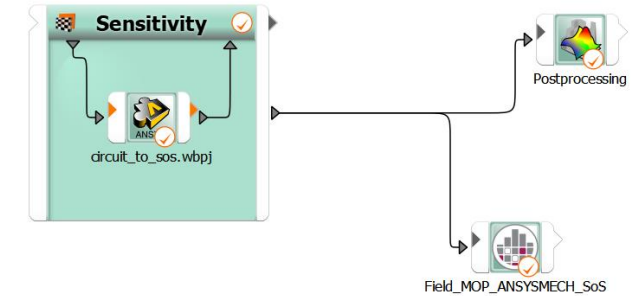
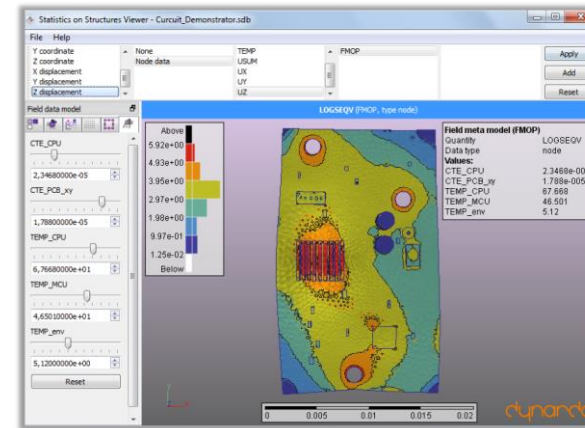
Statistics on Structures

- Integrate into ANSYS optiSlang Enterprise:

- Shared license
- 2D/3D Pre + Post GUI in optiSlang installer
- SoS integration nodes in optiSlang workflows:
 - Open 3D Viewer
 - Create Field MOP
 - Solver for Field MOP and Random Fields
- Mechanical/Workbench Plugin
- SoS Python module + FMOPSolver.dll

- Recent developments in

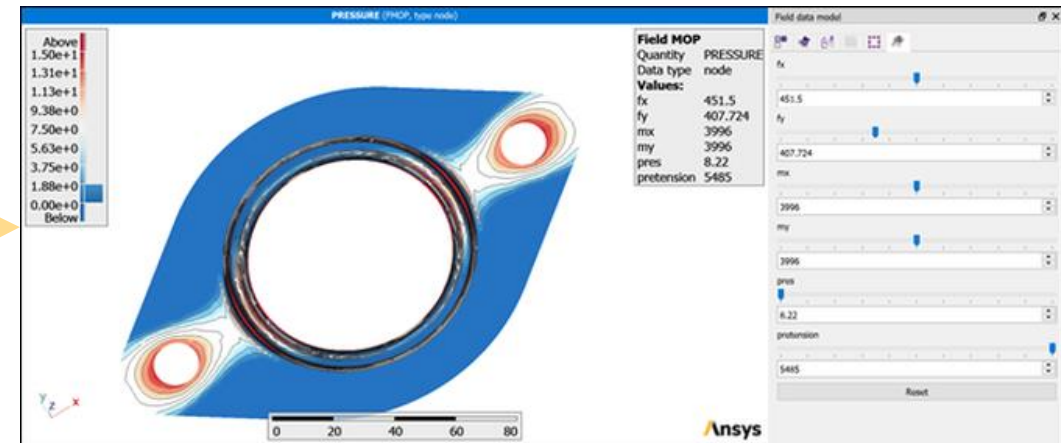
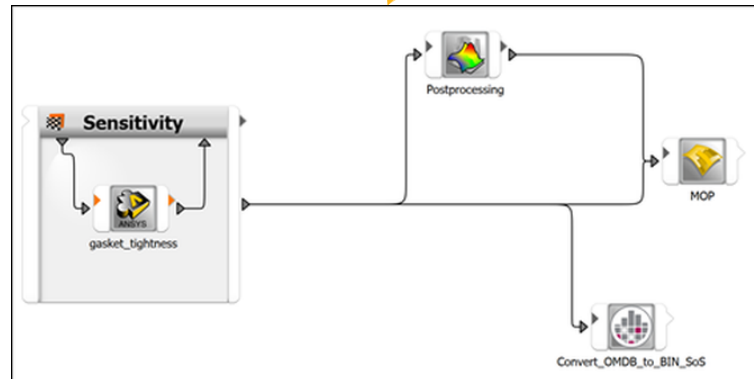
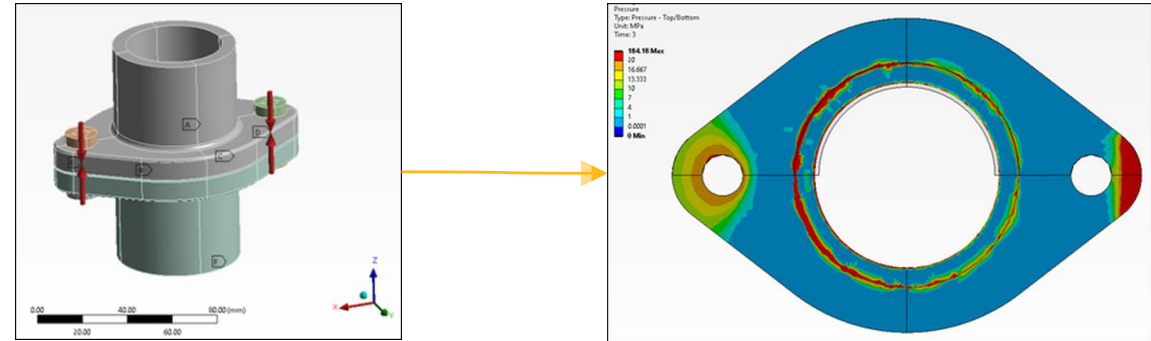
- Signal MOP (1D)
- Field MOP (2D/3D)
- Morphing for Uncertainty Quantification



Field meta models

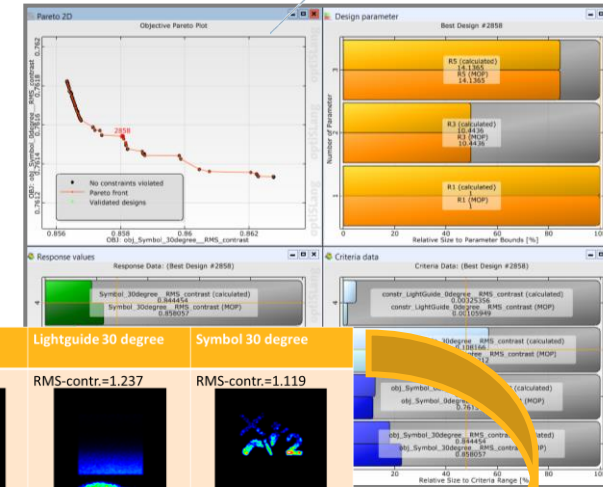
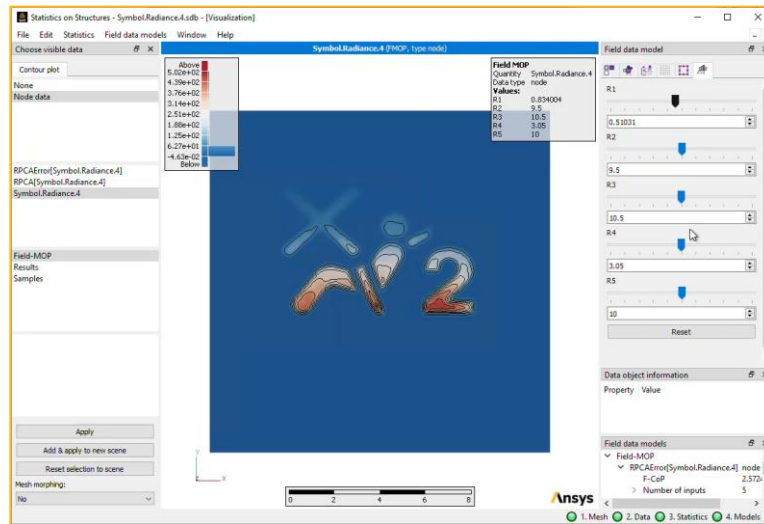
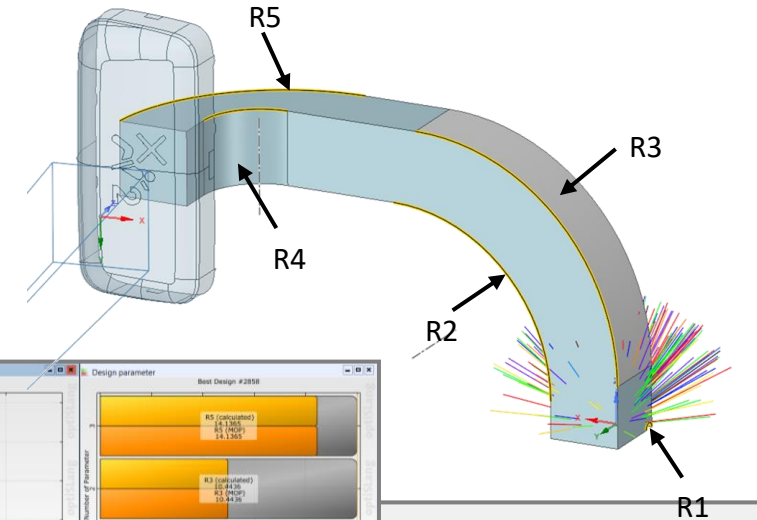
Customer example: ROM for real-time design studies

- Validate if a gasket is „tight“ in real-time what-if-scenarios
- Need to approximate resulting temperature, contact pressure and flow fields in real-time
- Based on these: analyse in 3D if the gasket is tight (true/false)

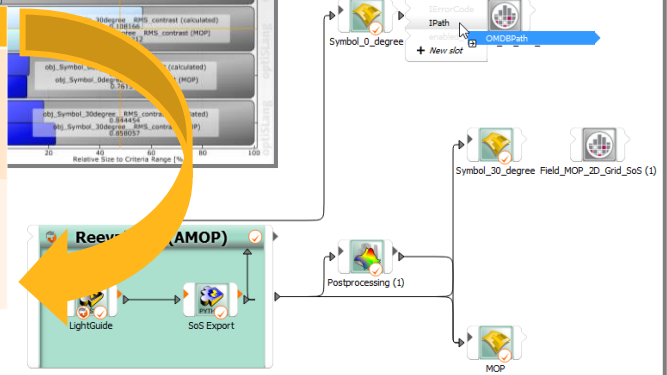


Customer Example: Optimize interior Lightguide layout using scalar & field analysis

- Optimize the shape of the light guide to get the best RMS-contrast
- Perform live design exploration and what-if analysis regarding luminance homogeneity with Field MOP

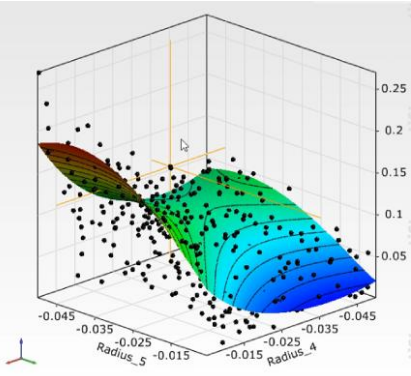
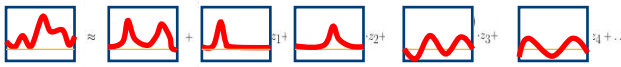
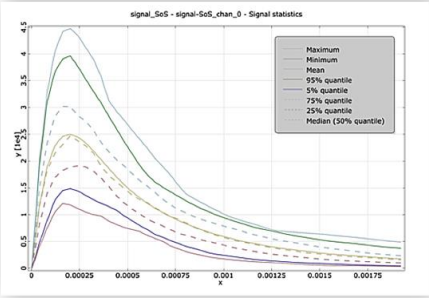
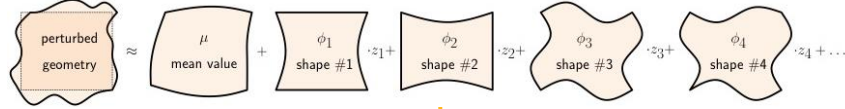
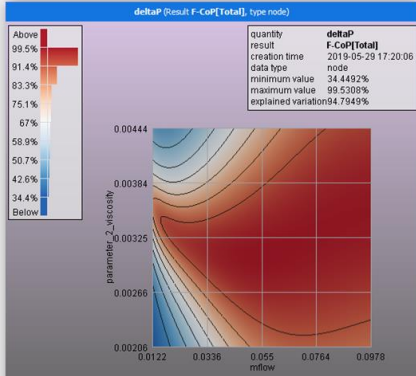



	Lightguide 0 degree	Symbol 0 degree	Lightguide 30 degree	Symbol 30 degree
Initial Design	RMS-contr.=0.703	RMS-contr.=0.805	RMS-contr.=1.237	RMS-contr.=1.119
Best Design	RMS-contr.=0.597	RMS-contr.=0.762	RMS-contr.=0.492	RMS-contr.=0.844



- Contact: sabrina.niemeyer@ansys.com

From Scalars to Signals and 2D/3D Fields

<p>0D: Scalars</p> <p>Ansys / OPTISLANG</p> <p>[Premium]</p>	<p>1D: Signal</p> <p>Ansys / OPTISLANG</p> <p>[Enterprise] module Statistics on Structures</p>	<p>2D: e.g. Wavefronts, Performance maps</p> <p>Ansys / OPTISLANG</p> <p>[Enterprise] Statistics on Structures</p>	<p>3D: Stress fields, deformations</p> <p>Ansys / OPTISLANG</p> <p>[Enterprise] Statistics on Structures</p>
<p>MOP</p>	<p>Signal-MOP</p>	<p>Field-MOP</p>	
	<p>  </p> 	<p>  </p>  	

Prognosis quality: Field Coefficient of Prognosis (F-CoP)

- Check prognosis quality in Field CoP matrix:

- Single value (“easy to use”)
- Indicates high or low model accuracy at a glance
- Is an average value of the CoP in space

	LOGSEQV	TEMP	UX	UY	UZ
F-CoP[CTE_CPU]	7.75 %	2.29 %	1.75 %	1.67 %	1.95 %
F-CoP[CTE_PCB_xy]	18.73 %		15.92 %	14.99 %	4.01 %
F-CoP[TEMP_CPU]	31.42 %	31.63 %	53.71 %	43.62 %	87.40 %
F-CoP[TEMP_MCU]	12.91 %	5.52 %	4.18 %	2.84 %	1.59 %
F-CoP[TEMP_env]	55.24 %	61.74 %	28.39 %	40.77 %	5.09 %
F-CoP[Total]	84.42 %	94.52 %	94.86 %	94.84 %	94.99 %

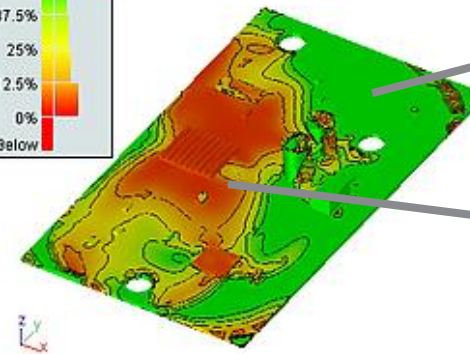
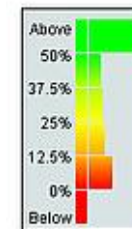
Sensitivity to inputs

Prognosis quality

- Check prognosis quality in Field-CoP 3D plot:

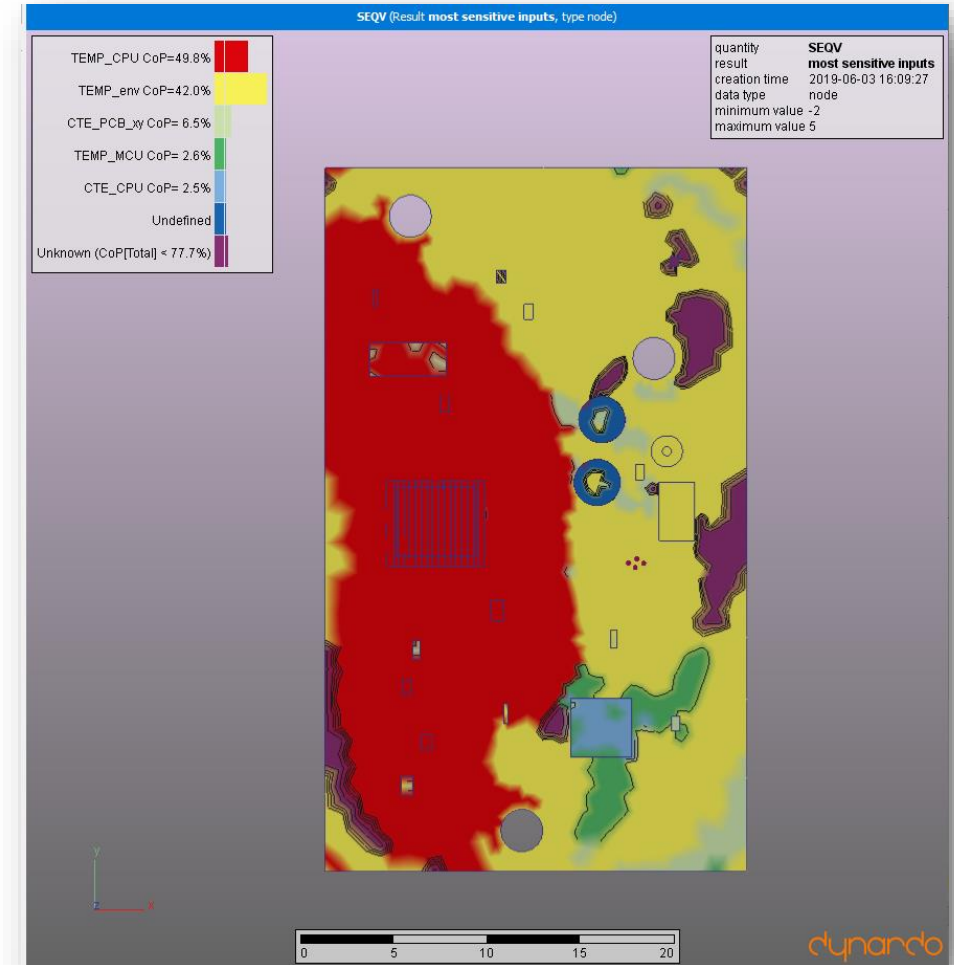
- Plots prognosis quality for each position
- Compare with standard deviation as an indicator of the magnitude of variation

- Accept / Repair model / Add designs ?



Sensitivity analysis: See all in a single plot

- Which parameter has the largest influence at what location ?
- Where has the ROM a too low accuracy ?
- Further post processing:
 - Use statistical measures to understand the statistics of variations at each position (e.g. mean value, standard deviation, quantiles....)
 - Plot variation patterns to identify correlations in space



21R2: Improved Signal MOP creation in optiSLang GUI

- Move Signal MOP from external models to „All internal models“
- Simplify settings of Signal MOP
 - Lean settings,
 - Easy to understand,
 - Improved consistency with scalar MOP and with Field MOP in SoS GUI
 - Removed features:
 - separate options for random signal modelling,
 - FMU export (can be done manually in SoS GUI)

MOP

Database file: Absolute path C:/Users/kuehn/Desktop/signal_mop_osl751_sos800/MOP.omdb

Settings Message log

Use advanced settings

Advanced Settings Signal MOP Settings

Property	Value
> Transformation	
> Models	
> Polynomials	
Use	<input checked="" type="checkbox"/> True
Order	2
Coefficient factor	2.00
> Moving least squares	
Use	<input checked="" type="checkbox"/> True
Order	2
Coefficient factor	8.00
> Kriging	
Use	<input checked="" type="checkbox"/> True
Anisotropic	<input type="checkbox"/> False
Coefficient factor	8.00
> Feedforward_network	
Use	<input type="checkbox"/> False
> Signal MOP	
Use	<input checked="" type="checkbox"/> True
> External	
ASCMO	<input type="checkbox"/> False
> Filter	

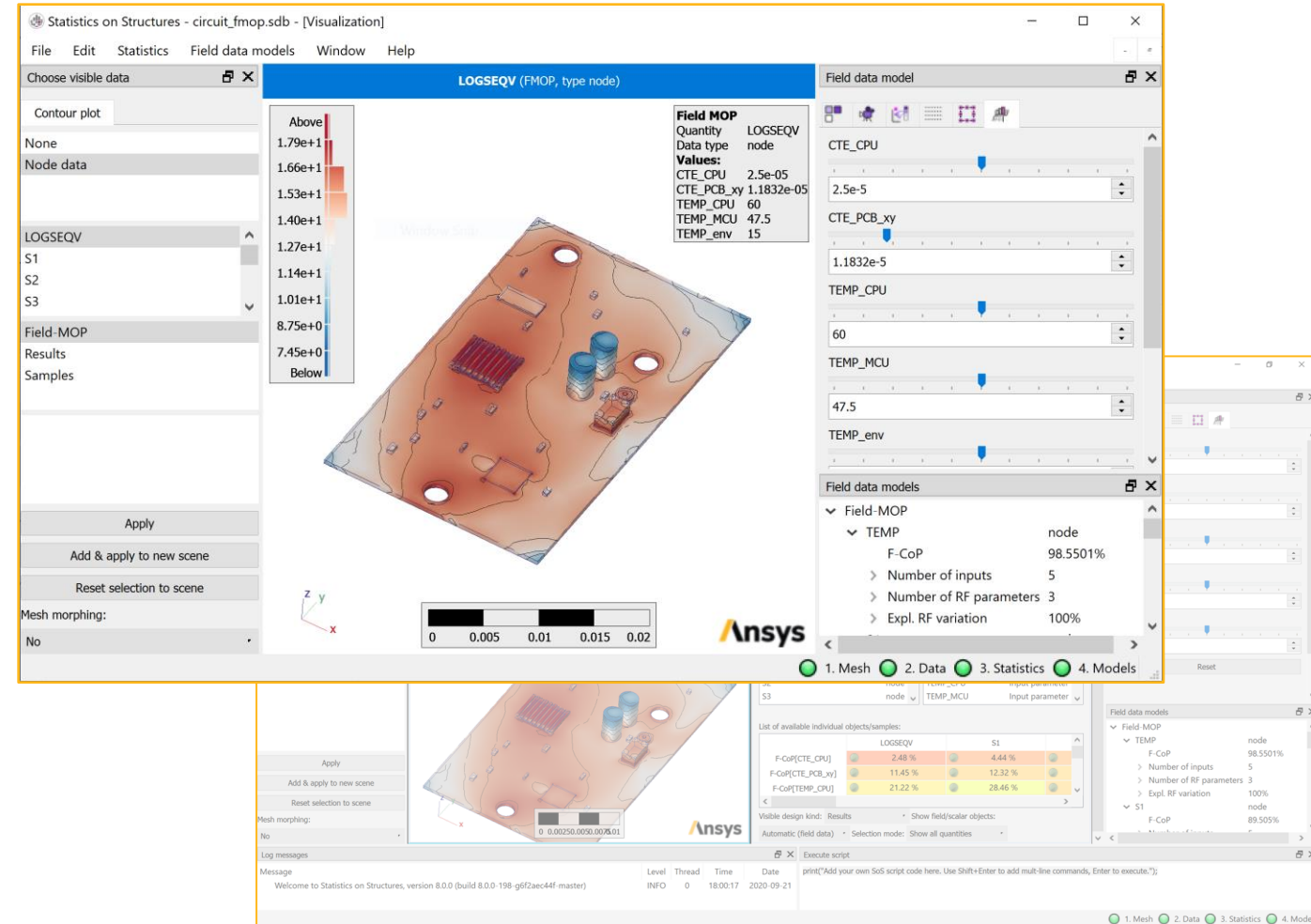
Maximum
Minimum
Mean
55% quantile
5% quantile
75% quantile
25% quantile
Median (50% quantile)

Time	Log level	Message
12:14:37.693287	INFO	Removing cross validation values from...
12:14:37.689289	INFO	Removing cross validation values from...
12:14:36.647893	INFO	Removing cross

options OK Cancel Apply

21R1: New SoS GUI for 3D Pre & Post Processing

- New user experience for beginners and advanced users
 - Central focus is 3D visualization and plotted data
 - Traffic light bar shows status and leads beginners through analysis
 - Configurability: Allow advanced access to log messages, data table, script terminal, autosave log etc.
 - Move user's guide and tutorials to ANSYS website



21R1: Python3 module for optiSLang

- SoS Python3 module
 - Includes TMATH module for linear algebra
 - 100% compatible with Numpy arrays
 - Full access to all SoS functions except visualization
 - Can be called from Custom Integration nodes or Python node in optiSLang
 - Script API Documentation available on the Ansys Help API Documentation site.
-
- 21R1: Introduce first API
 - 21R2: Introduce API doc (beta)

```
1 from sos_package import sos, tmath
```

```
1 sos_importer = sos.ImportDesigns( sos.referenceDesign() )  
2 sos_importer.base_path = join( designs_base_dir, ".." )  
3 sos_importer.design_name_format = "Design_(\\d+)"  
4 sos_importer.scanDesignRanges()
```

Towards user-friendly consumption of nD -ROMs

Macro Workflows

- Provide a user-extensible calculator for operations on field data
- Easy-to-use connection of
 - nD ROMs with optimization through FMU
 - Field MOP Solvers / 3D ROMs with 3rd party
 - No scripting necessary, but still flexible + fast
- Operators:
 - Linear algebra on vectors
 - Statistics
 - Extract data
 - Approximate random fields and Field MOP

Manage macros

Macros saved in this project:

Ident	Short name	FMU	SDB	2x?	@#
createDummyInputs	Create dummy inputs for test				
elementApproxFieldMOP	Evaluate Field-MOP	<input checked="" type="checkbox"/>			
elementEvalRF	Evaluate random field	<input checked="" type="checkbox"/>			
elementGetMax	Maximum value	<input checked="" type="checkbox"/>			
elementGetMin	Minimum value	<input checked="" type="checkbox"/>			
elementSetValue	Set value	<input checked="" type="checkbox"/>			
elementSub	Difference	<input checked="" type="checkbox"/>			
elementSum					
elementVec3N					
elementVonM					
identifyContac					
nodeApproxFi					

Add

Custom solver definition

Define a FMU solver by combining pre-defined or custom macros

Function	Quantity ident	Data type
> Evaluate Field-MOP		
Minimum value		
input	pstrain	element quantity
output	min[pstrain]	scalar quantity
Set value		
input	pstrain	element quantity
output	oldent[pstrain]	element quantity
param	new_value	scalar quantity
param	namedSelection	string

Select a function [dropdown] Add Remove

Set value

Sets all or a part of a field vector to a defined value. If the value of only a part is to be set then the ident of the respective named selection can be chosen. The modified field vector is stored in rthe database and associated with a new ident.

Inputs

- **ident** [input element ident]
The ident of the original field quantity.
- **new_value** [input scalar ident]
The new value of the output field vector at the respective locations

Outputs

- **ident** [output element ident]
The ident of the modified field quantity.

Further arguments

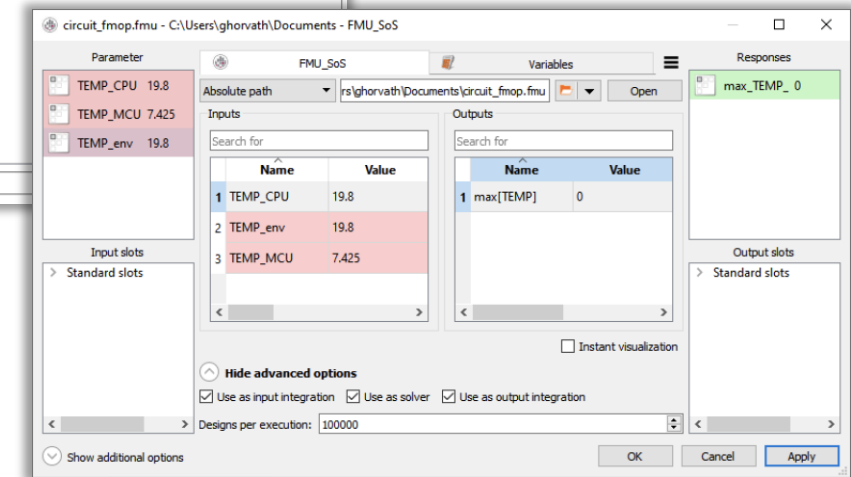
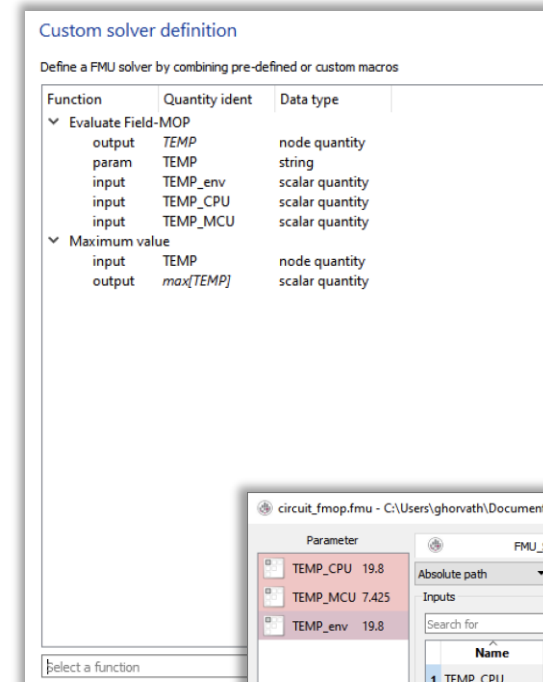
- **namedSelection** [string]
The ident of the named selection, if empty then all active data points are used.

Next Cancel

Use macros inside FMU 2.0

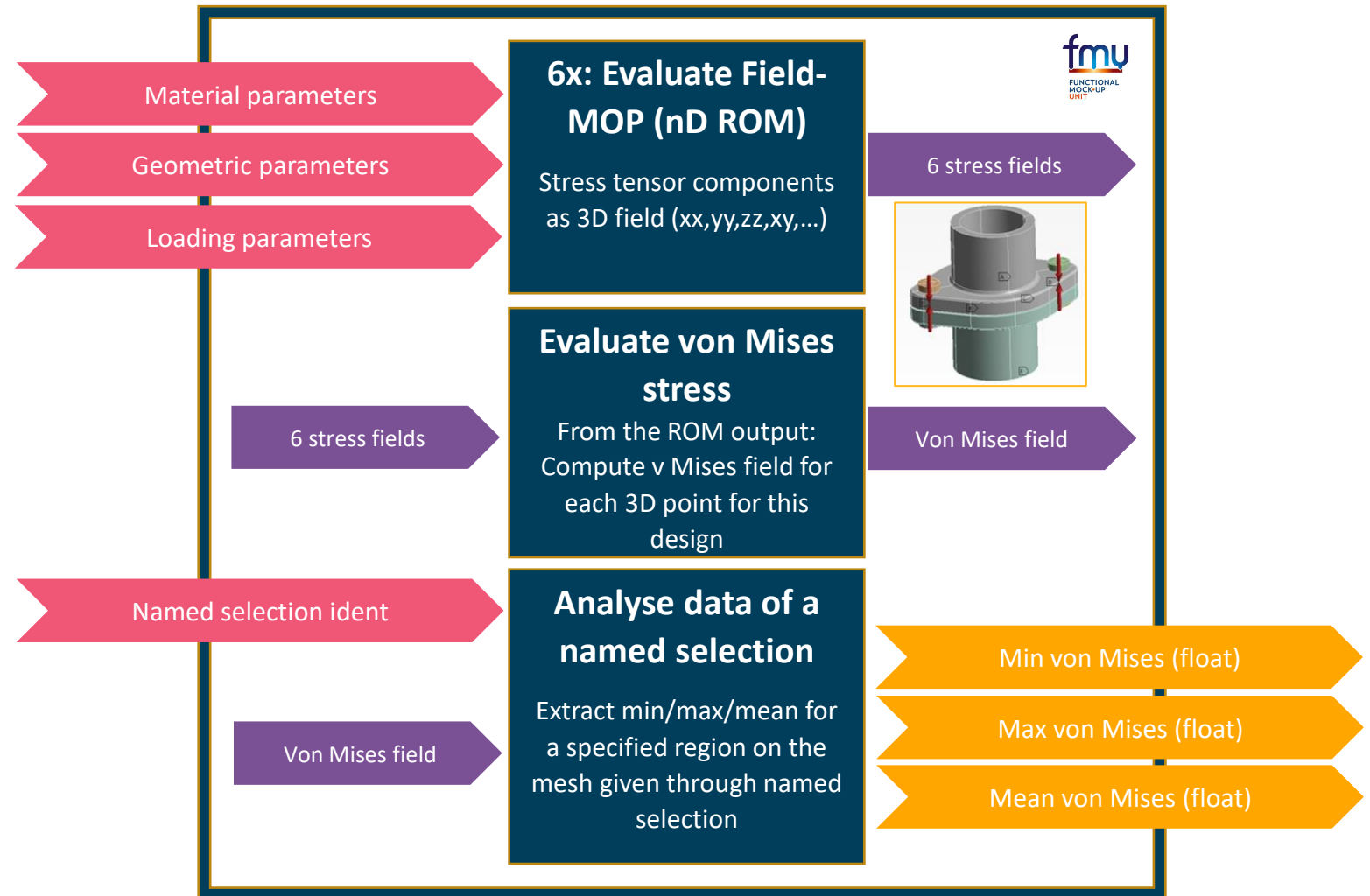
- Combine multiple macros into a single automated analysis
- Export entire workflows to FMUs
- Consume FMU in optiSLang or TwinBuilder
- Visualize all 3D fields afterwards in SoS post processing

- 8.0: Initial version (FMU 2.0 model exchange)
- 21R1: Export both types – model exchange and co-simulation - into a single FMU file
- 21R2: Use more built-macros, improve consumption of SoS FMUs in optiSLang workflows



Example FMU workflow: Standard macros

- Approximate stress tensor with Field MOP
- Evaluate von Mises stress
- Extract min/max/mean at specific sub region
 - Or: Extract sub space components for efficient system simulation
- Save an SDB file with all intermediate results for interactive post processing



21R2: Use macros inside SoS GUI

- Call and apply macros to data being already loaded in SoS GUI
- Set parameters of macros (designs, inputs, outputs, etc.)
- Save and visualize results in .SDB
- Write and test macros for your customers, deployed as an .SDB file.

The screenshot displays the SoS GUI interface for selecting and configuring a macro. The main window is titled "Select Macro To Execute" and features a search bar and two tabs: "element" and "node". A list of macros is shown, with "Compare objects: difference" selected. The details for this macro are displayed on the right, including its description, inputs, and outputs. A secondary window is open, showing a list of designs (1-13) and a configuration panel for the "Compare objects: difference" macro. The configuration panel includes dropdown menus for "referenceQuantity" and "relativeQuantity", both set to "mstress".

Select Macro To Execute

filter... element node

- Compare objects: difference**
elementCompareDifference
- Compare objects: relative accuracy**
elementCompareAccuracy
- Compare objects: signed error**
elementCompareSignedError
- Compare objects: unsigned error**
elementCompareUnsignedError
- Compress field to RF coefficients**
elementCompressField
- Compute the RPCA**
elementRPCA
- Create number**
scalarCreate
- Difference**
elementSub
- Evaluate Field-MOP**
elementEvaluateFieldMOP

Show script code before macro execution

Compare objects: difference

Compare two objects by absolute difference which is approximated minus the reference quantity.

Inputs

- **referenceQuantity** [input element id (string)]
The reference field quantity.
- **relativeQuantity** [input element id (string)]
The relative field quantity.

Outputs

- **difference** [output element id (string)]
The result of difference is saved in the database. A new quantity will be created with current design id.

Select designs

- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10
- 11
- 12
- 13

referenceQuantity
mstress

relativeQuantity
mstress

Compare objects: difference

Compare two objects by absolute difference which is approximated minus the reference quantity.

Inputs

- **referenceQuantity** [input element id (string)]
The reference field quantity.
- **relativeQuantity** [input element id (string)]
The relative field quantity.

Outputs

- **difference** [output element id (string)]
The result of difference is saved in the database. A new quantity will be created with current design id.

Further arguments

- **database** [database]
Internally used.
The database object this macro is working on.
- **design** [design id (string)]
Internally used in FMU workflows.
The design id serving as input and output for this macro.

Modeling of imperfect structures for UQ

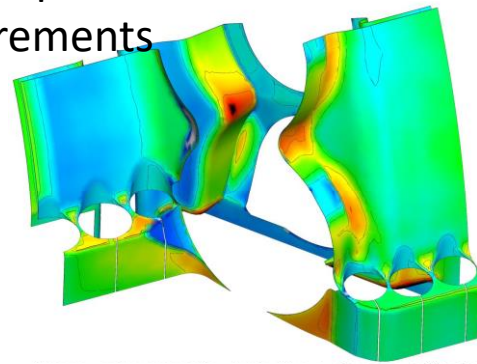
Customer story:

How do manufacturing tolerances affect low-cycle fatigue ?

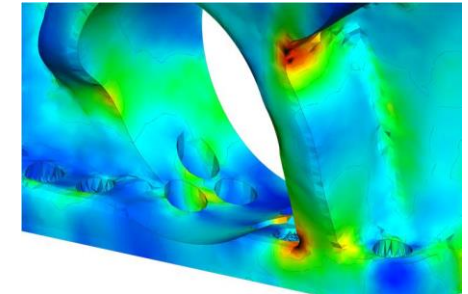
- Casting process (here: gas turbine housings)
- Question: How do geometric imperfections in production influence stress / fatigue behavior ?



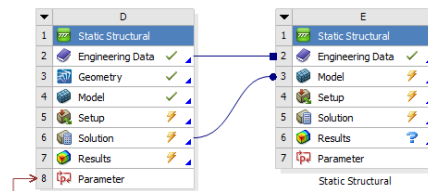
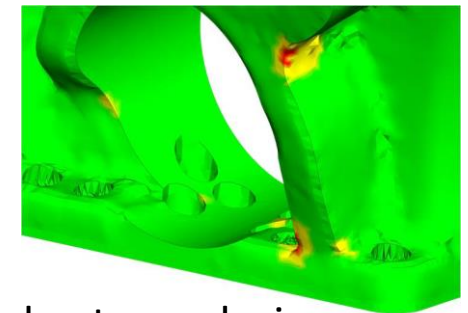
Mean imperfection from measurements



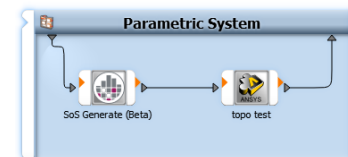
Mean stress



Mean+1·Sigma (~ 68,3%)



Stresses + Temp: ANSYS



optiSLang: 100 robustness designs

SIEMENS

With courtesy of SIEMENS (source: Lohse et al, DVM Probabilistic Workshop 2016)

How to deal with measurements in FEM, e.g. geometries ?

a) Validation

Apply measurement

- Create CAD0 geometry and mesh
- Determine geometric deviations to measurement (STL)
- Morph mesh and compute structural performance

b) Uncertainty quantification

Robustness and Reliability Analysis

- Create CAD0 geometry and mesh
- Determine geometric deviations to several measurements (STL)
- Create a **statistical shape model**
- **Generate artificial geometries** for DOE and use morphed FEM meshes in CAE



Apply Measurement of Scanned Models

- General Scheme of the Workflow:

1. STL File from GOM Measurement
2. ANSYS Mechanical Mesh of nominal Geometry

Import into SoS

Automizable workflow using optiSLang for variational analysis

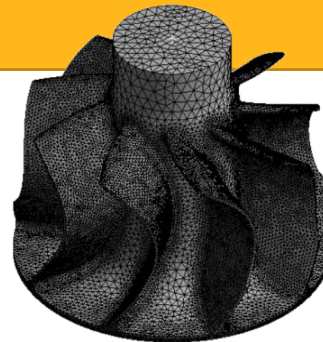
Statistics on Structures

- Differences between STL and Mesh are evaluated
- SoS automatically generates APDL commands for mesh morphing inside ANSYS to fit the nominal mesh to the real (STL) geometry



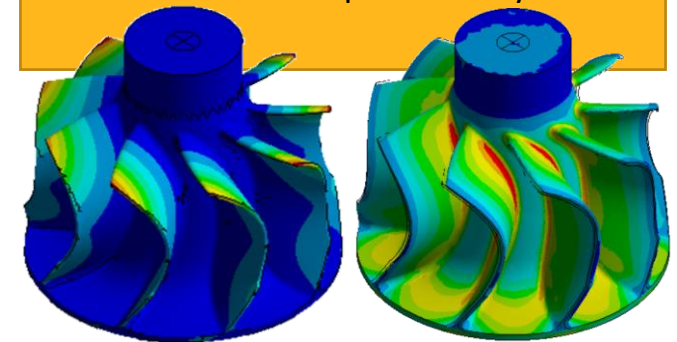
ANSYS Mechanical Mesh Update

- Morphing commands are imported into ANSYS Mechanical
- Mechanical Mesh update



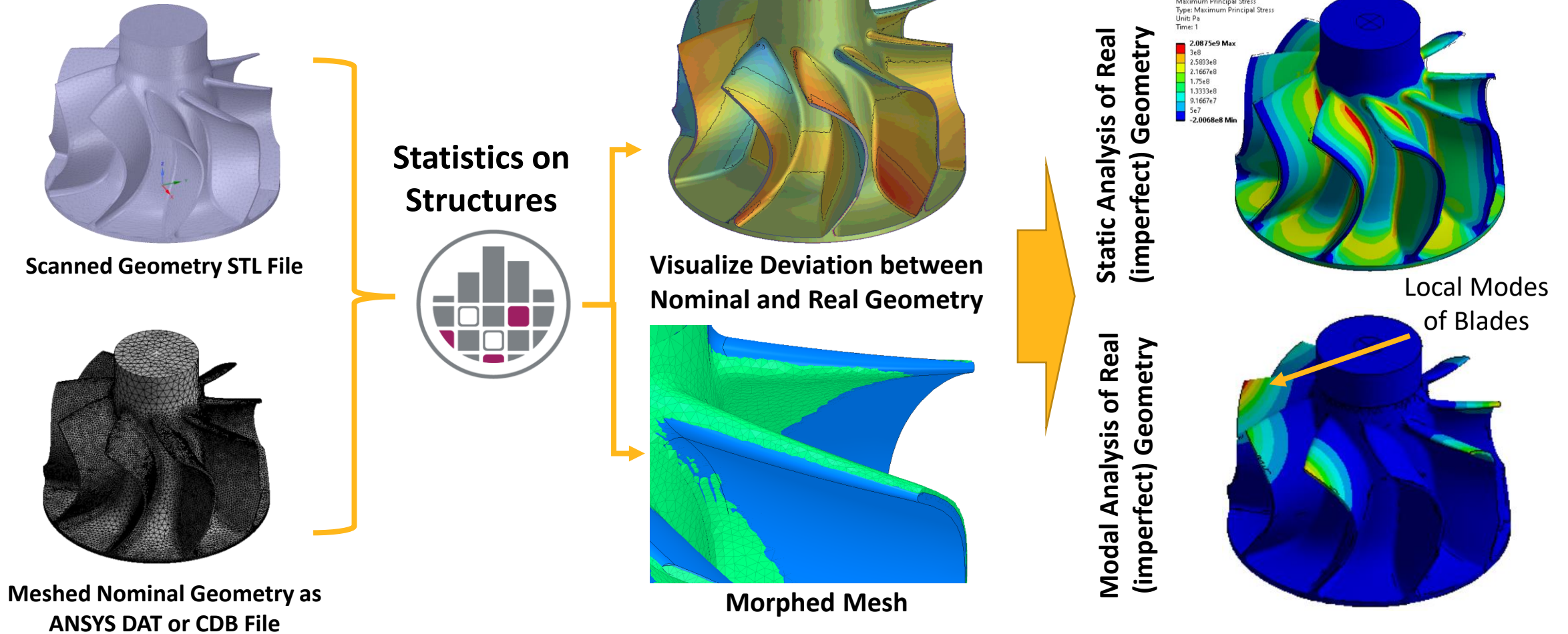
ANSYS Mechanical Analysis on updated Mesh

- Static Structural Analysis
 - Modal Analysis
- Forced Response Analysis



Apply Measurement of Scanned Models 1:1 morphing

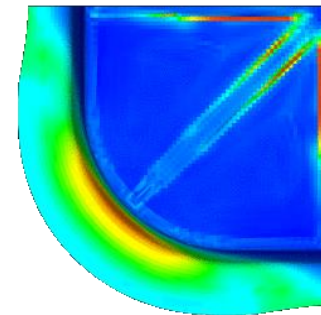
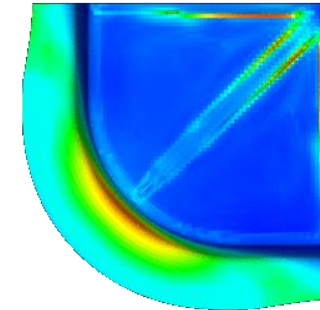
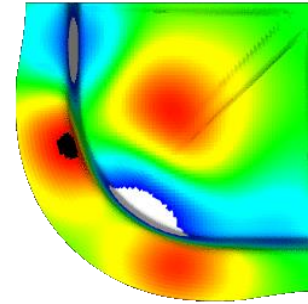
Impact on, e.g. Structural or Modal Analysis



UQ: Random fields depending on available data

Parameterization of geometric shapes

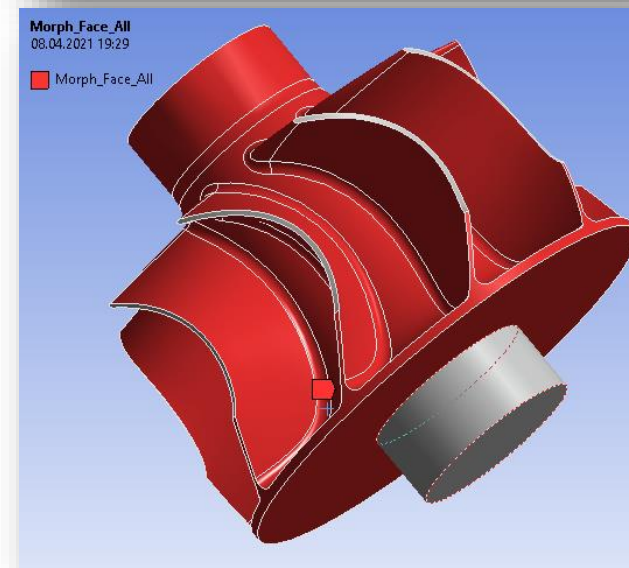
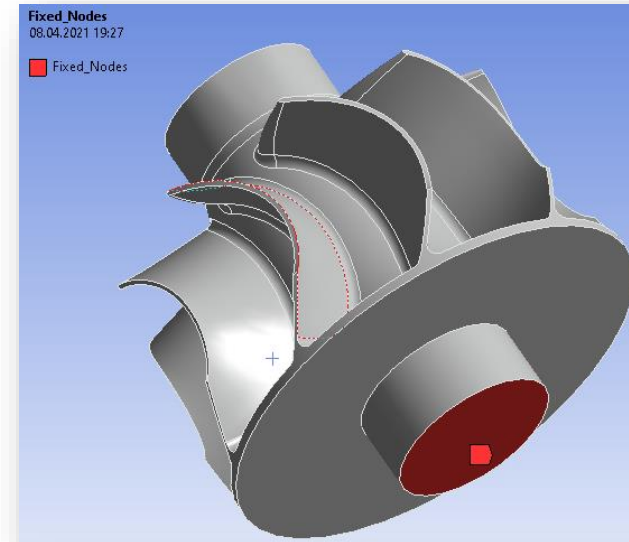
- 1. No/single measurement:**
assumptions
(synthetic random field model)
- 2. 3-5 measurements:**
empirical mean+stddev
assumed correlation
(synthetic random field model)
- 3. Many measurements:**
Empirical random field model
Anisotropic, inhomogeneous,
Non-Gaussian



21R2: Apply Measurement with SoS ACT Plugin (1/2)

ANSYS Mechanical:

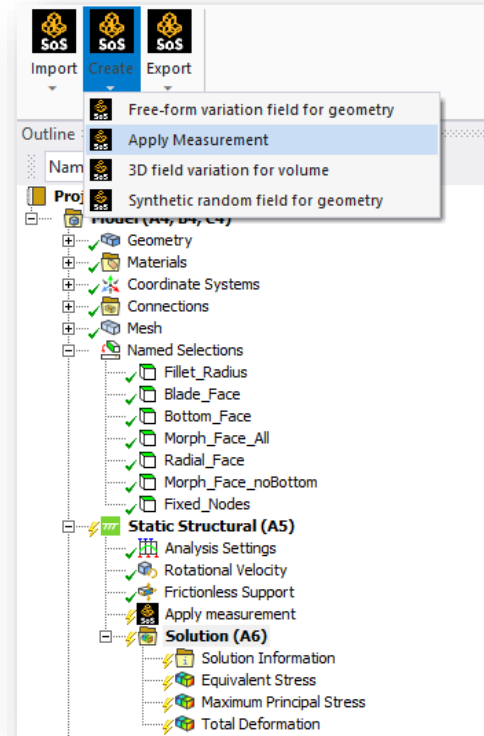
1. Prepare measured (laser scan) data in a carefully sanitized mesh format (STL)
2. Define named selections:
 - Fixed nodes (top)
 - Nodes to be morphed to target location (bottom)



21R2: Apply Measurement with SoS ACT Plugin (2/2)

New:

- Easy-to-use: directly perform mesh mapping + morphing within Ansys Mechanical.
- SoS' mesh mapper is running in the background



The screenshot shows the 'Details of "Apply measurement"' dialog box. It contains the following settings:

Boundary to be modified	
Scoping Method	Named Selection
Named Selection	Morph_Face_All
Fixed boundary	
Scoping Method	Named Selection
Named Selection	Fixed_Nodes
Mesh part to be exported to SoS	
Scoping Method	Geometry Selection
Geometry	1 Body
Scan data file (*.stl,*.dat,*.cdb)	
Scan data file	C:\TurbineWheel_Scan.stl
Advanced options	
Check for mesh stability	True
Linearize Morphing for quadratic elements	True
Maximum search distance	1 mm
Use mesh stabilization	True
Test on mesh distortion	False
Auto-delete bad elements	No
Enable visualization	On
Solver options	
Number of CPUs used by SoS (0=all)	0
Internal directory	SoS_MeshFromData_2

Summary: optiSLang SoS 2021 R2

Powerful analysis tools for model understanding and approximation

ROM: Improves operations on Field meta models using macros, FMU, simplified GUI and Python

UQ: Simplifies 1-to-1 mapping + morphing inside Mechanical plugin

Anslys

WO**ST**

CONFERENCE

