

$$\bar{\Pi} = \frac{1}{2} \sum_e \{u\}^T \cdot [K] \cdot \{u\} - \{u\}^T \cdot \{F\}$$

FEM SOFTWARE AND SERVICES



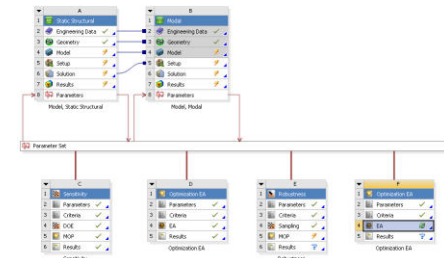
From Topology Optimization to Robust Design Optimization

Dipl.-Ing. Markus Kellermeyer, CADFEM GmbH

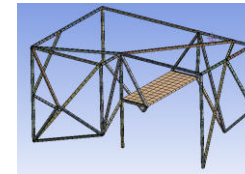
Robust Design Optimization

Outline

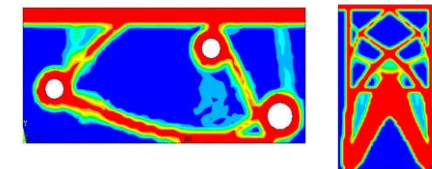
1. Overview for Optimization in ANSYS Workbench



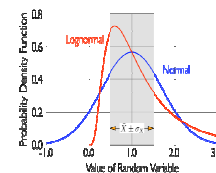
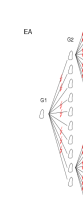
2. Project Description



3. Topology Optimization inside ANSYS Workbench

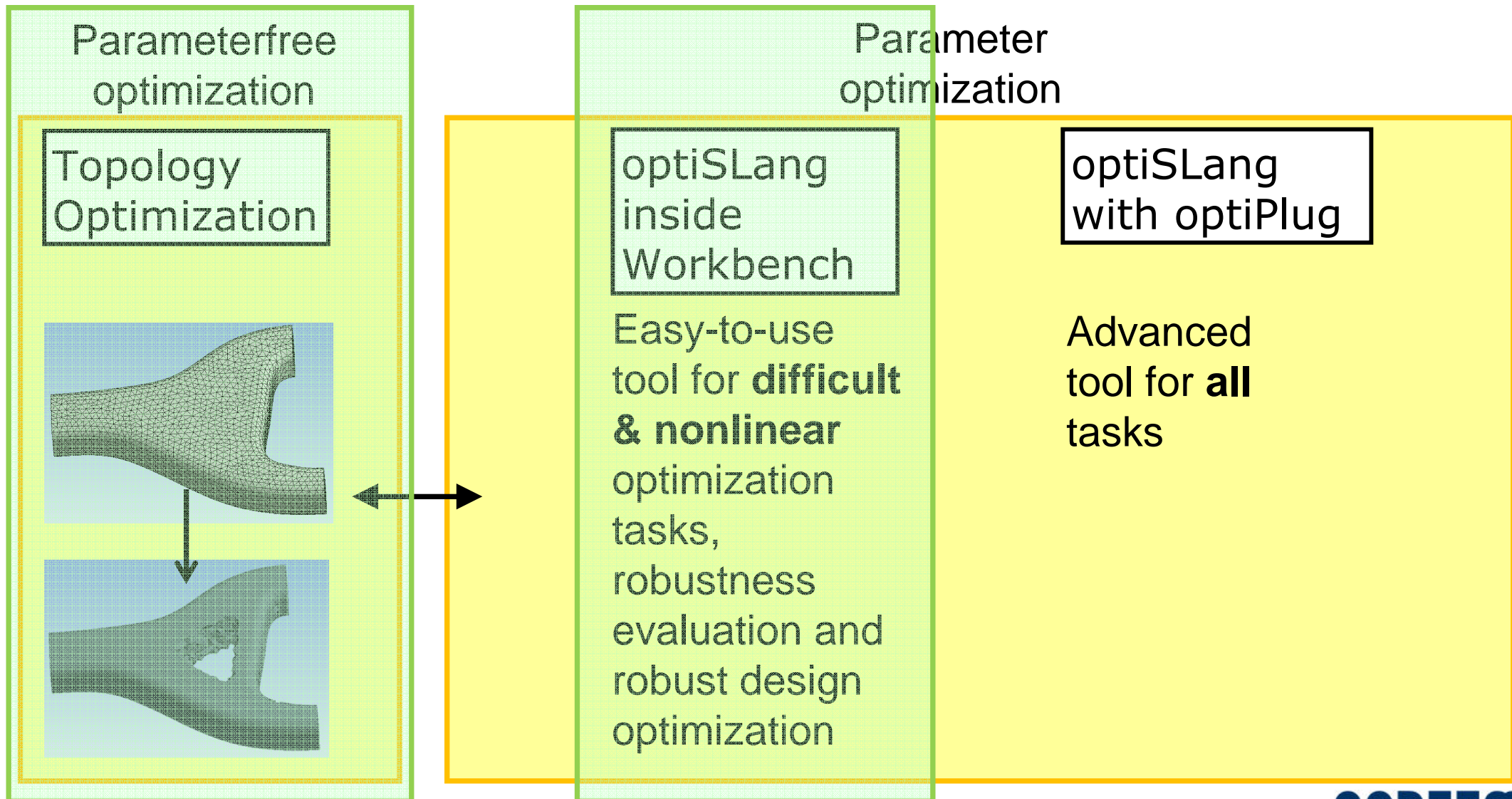


4. Robust Design Optimization with „optiSLang inside Workbench“



Robust Design Optimization

Overview for Optimization in ANSYS Workbench

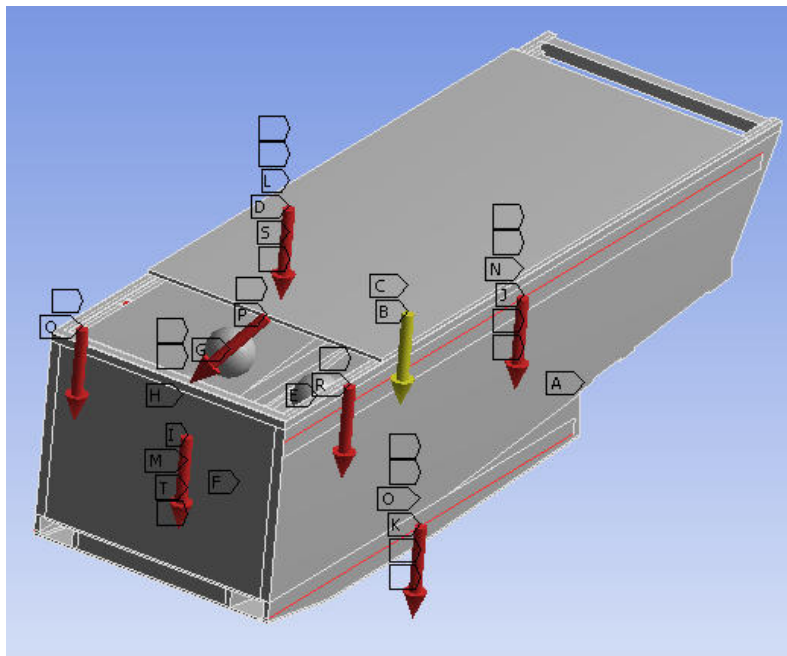


Robust Design Optimization

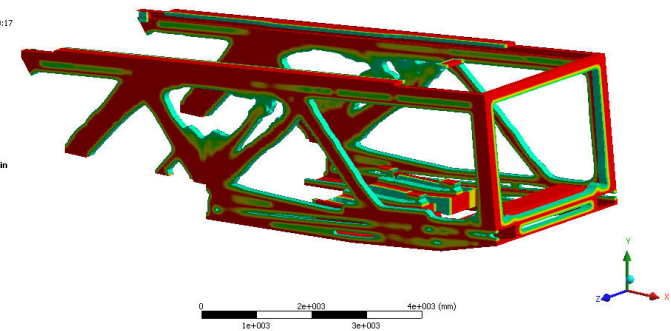
Example for Topology Optimization: PowerWind GmbH

6 different loadcases were considered

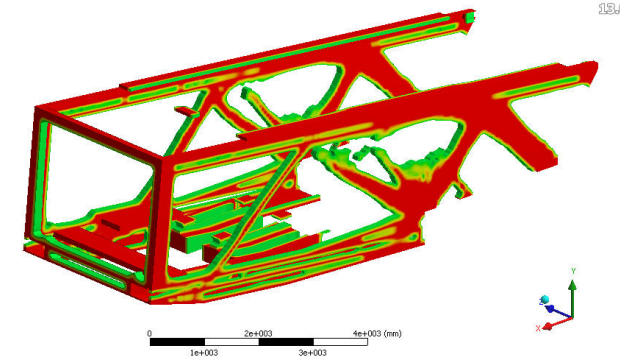
- Standard Earth Gravity
- Acceleration
- Fixed Support
- LF1_Wind_links
- LF1_Wind_links 2
- LF1_Wind_rechts
- LF1_Wind_rechts 2
- LF2_Schnee_links
- LF2_Schnee_links 2
- LF2_Schnee_rechts
- LF2_Schnee_rechts 2
- LF3_Winde
- LF3_Kran_links
- LF3_Kran_rechts
- LF3_Haubengewicht_links
- LF3_Haubengewicht_links 2
- LF3_Haubengewicht_rechts
- LF3_Haubengewicht_rechts 2
- LF4_Haubengewicht_links
- LF4_Haubengewicht_links 2
- LF4_Haubengewicht_rechts
- LF4_Haubengewicht_rechts 2
- LF5_Wind_links 3
- LF5_Wind_links 4
- LF5_Wind_rechts 3
- LF5_Wind_rechts 4
- LF6_Winde
- LF6_Kran_links
- LF6_Kran_rechts
- LF6_Haubengewicht_links
- LF6_Haubengewicht_links 2
- LF6_Haubengewicht_rechts
- LF6_Haubengewicht_rechts 2



E: Topology Optimization
TOPO
Expression: TOPO
Unit: kg
Time: 6
17.10.2011 10:17



E: Topology Optimization
TOPO
Expression: TOPO
Unit: kg
Time: 6
17.10.2011 10:12



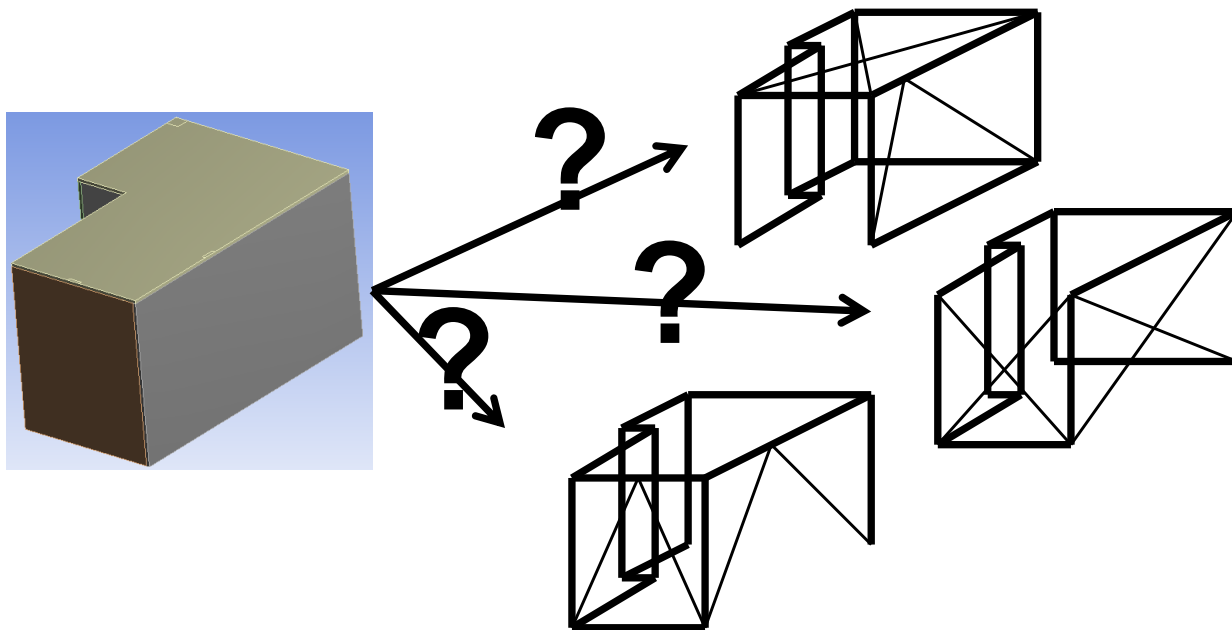
by courtesy of PowerWind GmbH

Robust Design Optimization

Project Description

Create a design within a predefined space, that

- consists of beams with predefined cross section profiles
- where the beams do not exceed a predefined stress
- where the 1st frequency will be as large as possible
- where the structure will be a 2- σ design or higher due to appearing stresses

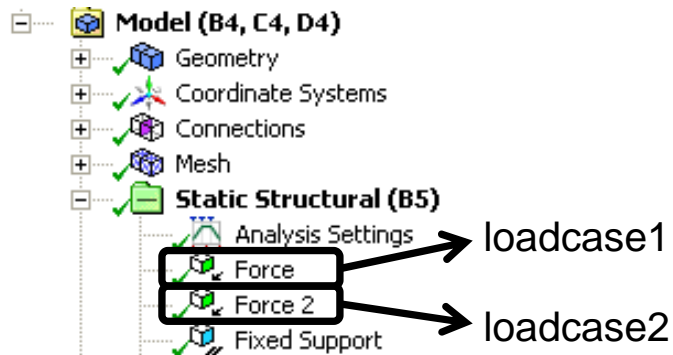


Robust Design Optimization

Topology Optimization

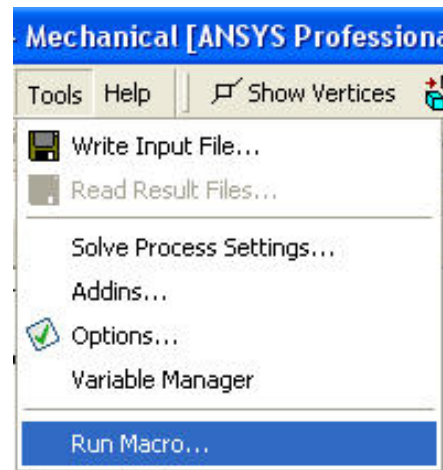
Steps to do topology optimization with several load cases:

Define several load steps...



These will represent the loadcases

Run Macro...



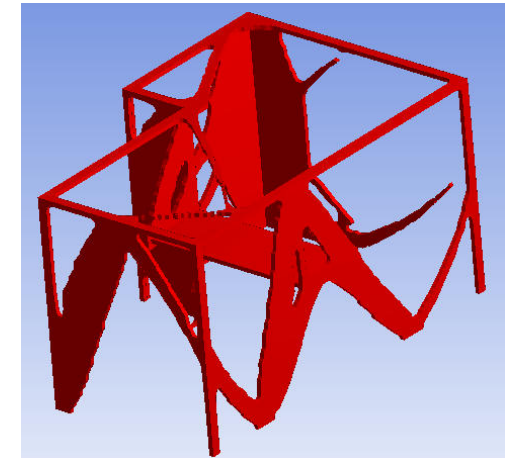
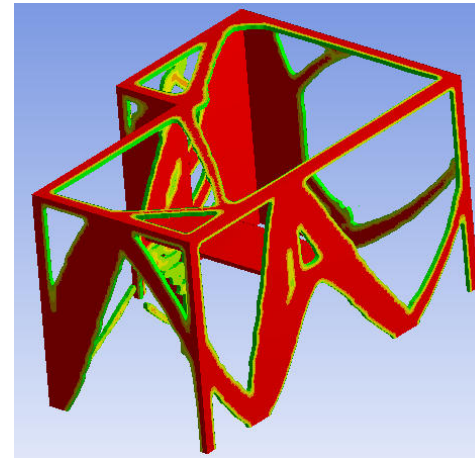
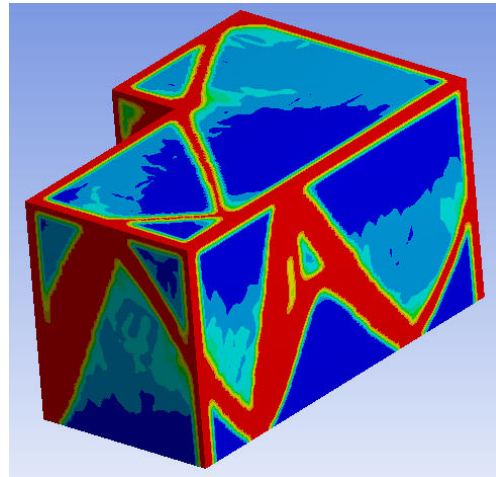
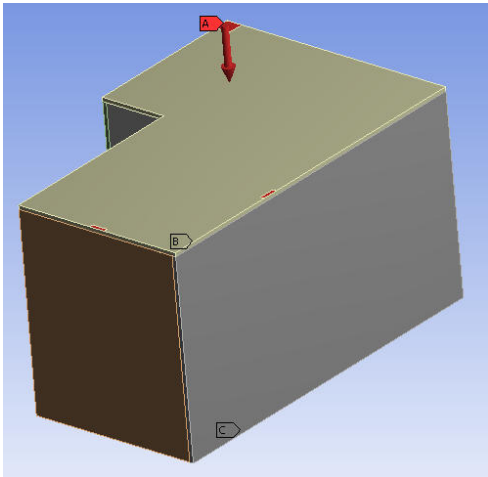
Topologyoptimization.js

Solve...



Robust Design Optimization

Topology Optimization



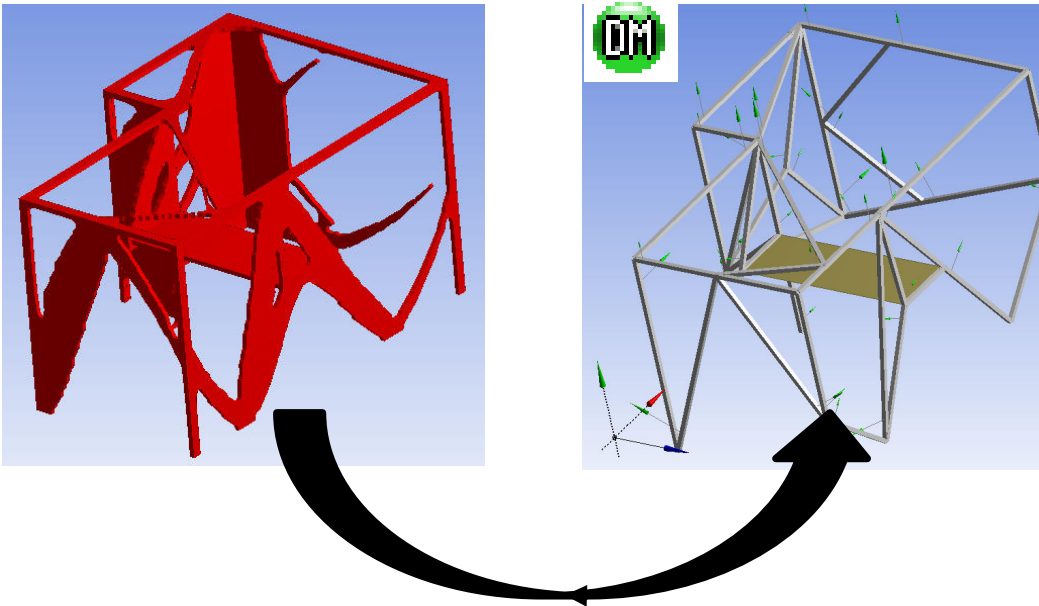
- Use Topology Optimization in Workbench
- Several load cases can be considered:
- a „one-click-solution“

 Topologyoptimization.js

Robust Design Optimization

Topology Optimization

Use topology idea, to create a manufacturable concept:



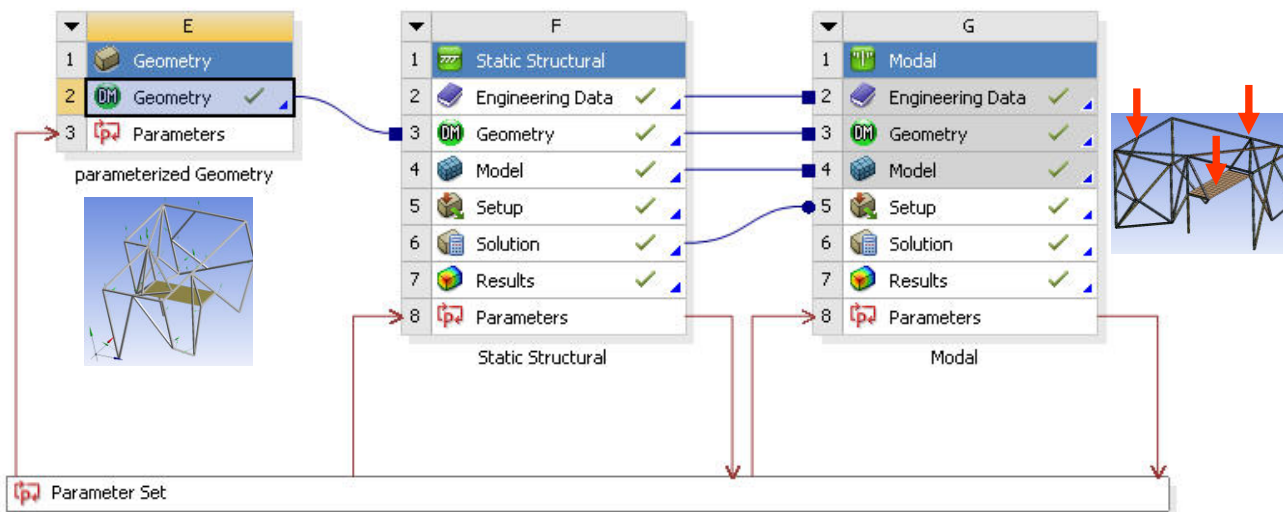
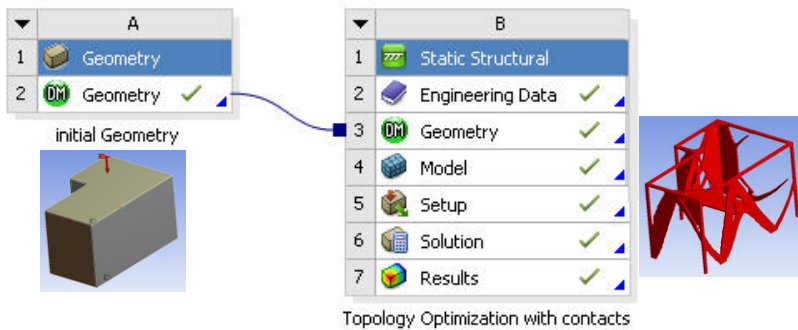
Parameterize the beam structure
to allow different design constellations:

Parameter Manager	
split1	= 0.64
split2	= 0.45
split3	= 0.75
split4	= 0.45
split5	= 0.65
split6	= 0.5

Robust Design Optimization

Topology Optimization

What's been done so far:



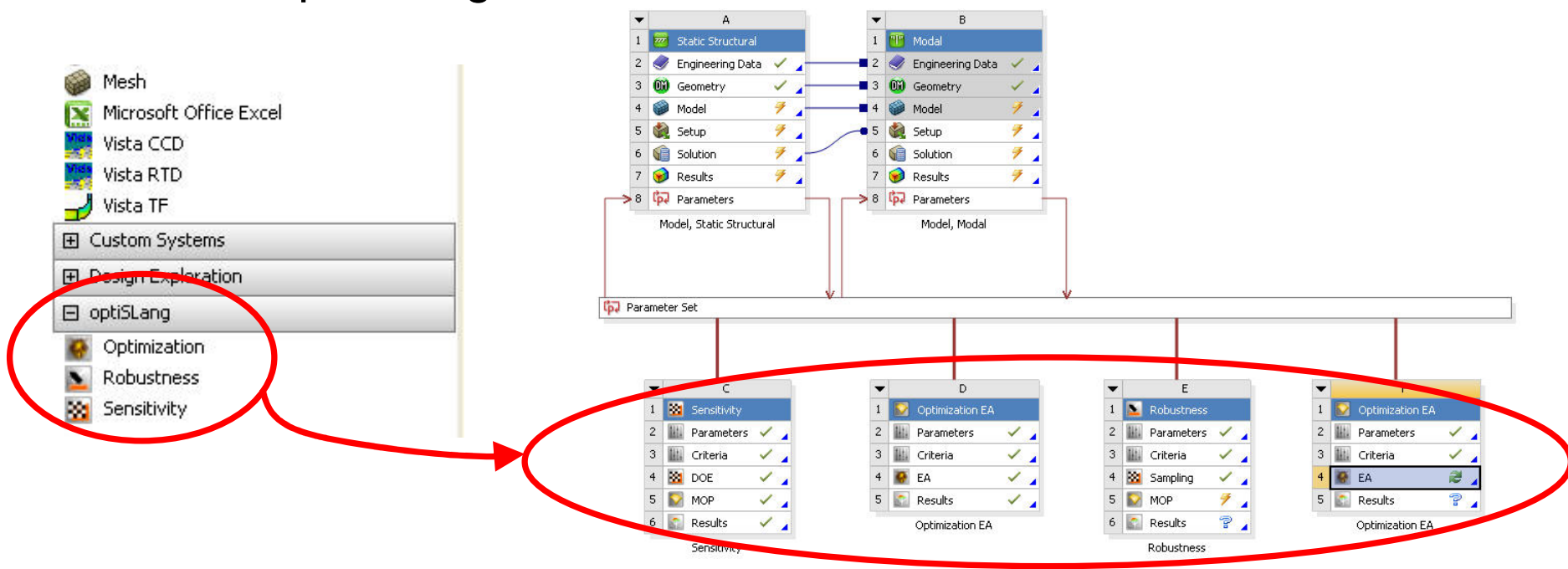
Robust Design Optimization

Robust Design Optimization with „optiSLang inside Workbench“

General Information:

Dynardo integrated „optiSLang“ in ANSYS Workbench as an easy-to-use tool.

It's called „optiSLang inside Workbench“



→ It will be used for the „Robust Design Optimization“ Workflow

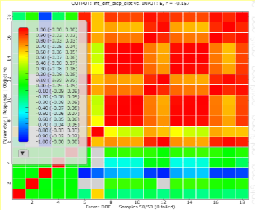
Robust Design Optimization

Robust Design Optimization with „optiSLang inside Workbench“

General Workflow:

Sensitivity Analysis:

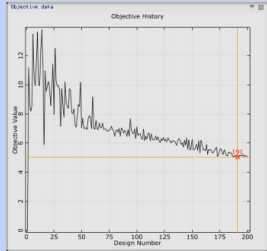
Input1 Input2
 Input3 Input4
 Input5 Input6
 Input7 ...



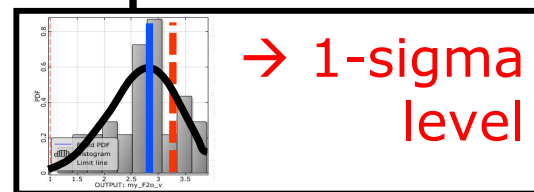
Optimization:

Input1 Input4
 Objectives
 Constraints

→ Input1' Input4'



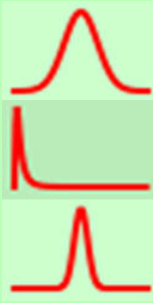
Modify Constraints
 for a new
 Optimization



Robustness Eva.:

Input1' Input2
 Input3 Input4'
 Input5 Input6
 Input7 ...

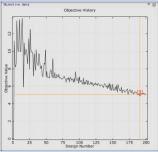
Constraints



Optimization 2:

Input1'' Input4''
 Objectives
 Constraints'

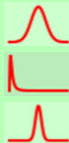
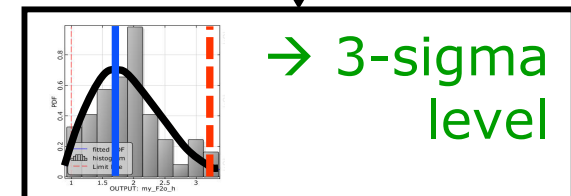
→ Input1''' Input4'''



Robustness Eva. 2:

Input1''' Input2
 Input3 Input4'''
 Input5 Input6 ...

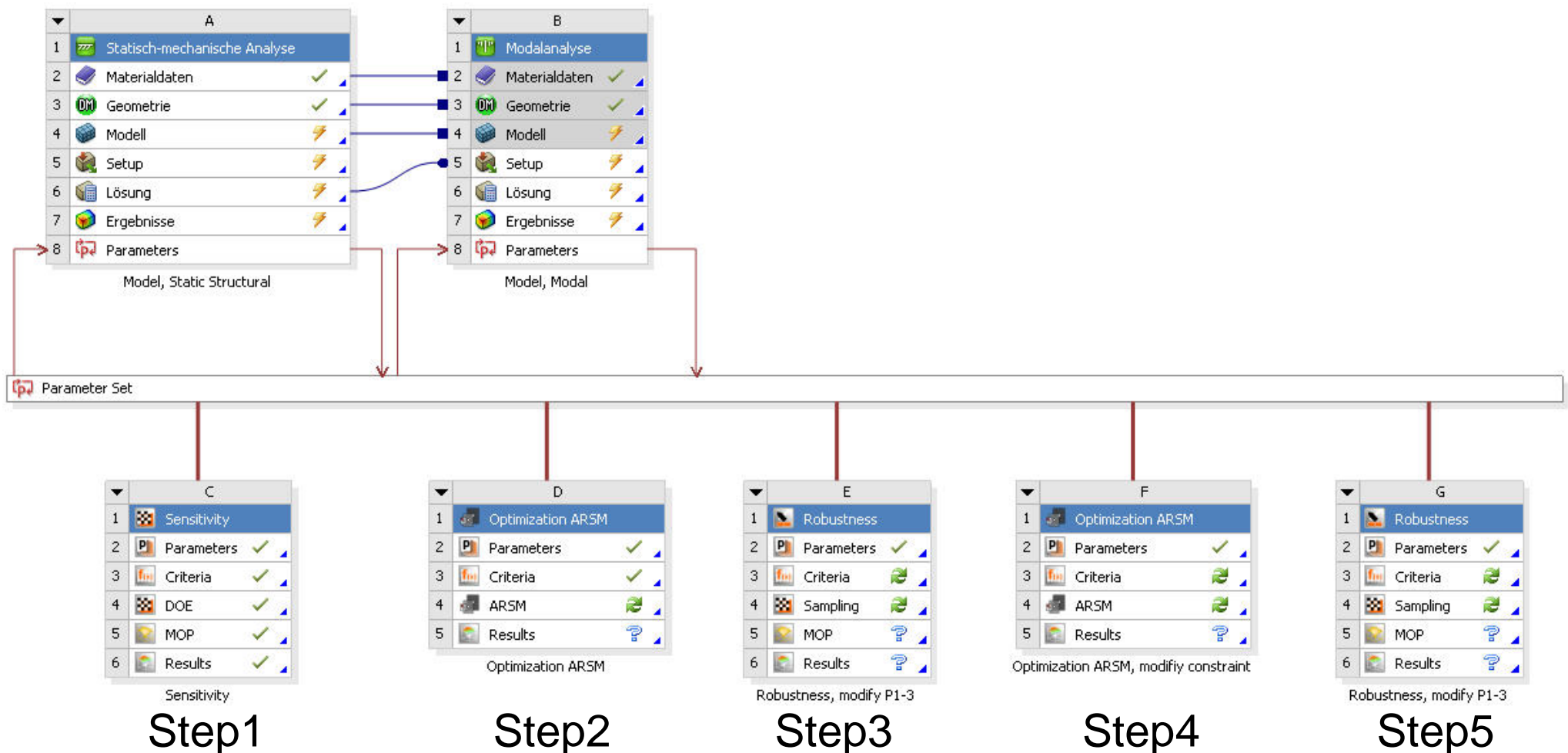
Constraints

Robust Design Optimization

Robust Design Optimization with „optiSLang inside Workbench“

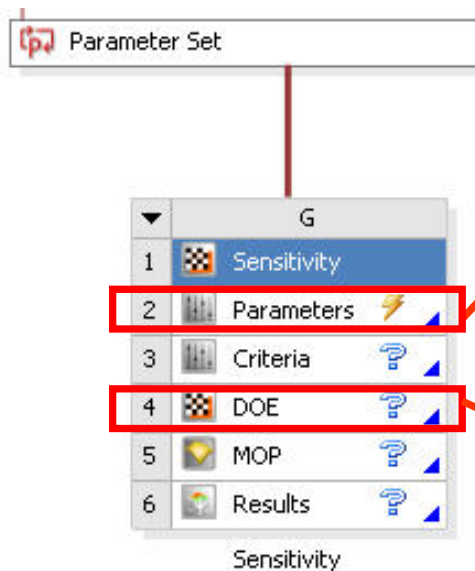
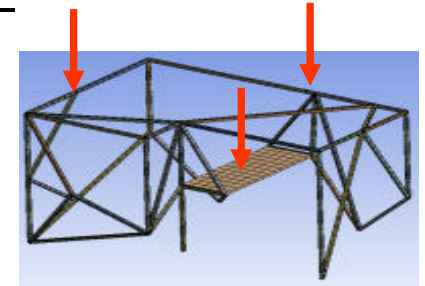
General Workflow in ANSYS Workbench:



Robust Design Optimization

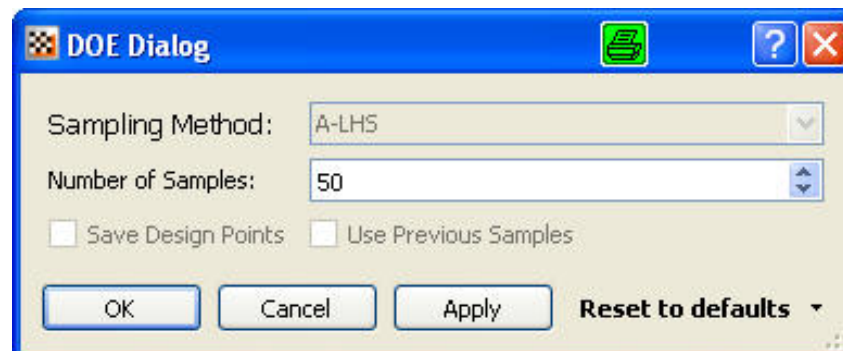
Robust Design Optimization with „optiSLang inside Workbench“

Step 1: Sensitivity Analysis - Setup



	Name	Parameter type	Reference value	Value type	Resolution	Constant	Range	Range plot	Summary
1	Force_2_...	Deterministic	100	REAL	Continuous	<input type="checkbox"/>	90 110		Force_2_X_C...
2	Force_2_...	Deterministic	-50	REAL	Continuous	<input type="checkbox"/>	-55 -45		Force_2_Co...
3	split1	Deterministic	0.3	REAL	Continuous	<input type="checkbox"/>	0.27 0.33		split1
4	split2	Deterministic	0.3	REAL	Continuous	<input type="checkbox"/>	0.27 0.33		split2
5	split3	Deterministic	0.4	REAL	Continuous	<input type="checkbox"/>	0.36 0.44		split3
6	split6	Deterministic	0.3	REAL	Continuous	<input type="checkbox"/>	0.27 0.33		split6
7	split7	Deterministic	0.2	REAL	Continuous	<input type="checkbox"/>	0.18 0.22		split7
8	split8	Deterministic	0.2	REAL	Continuous	<input type="checkbox"/>	0.18 0.22		split8

1. Define lower & upper bounds

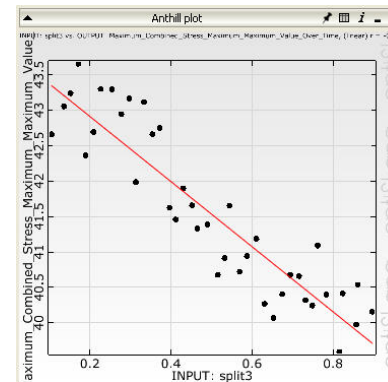
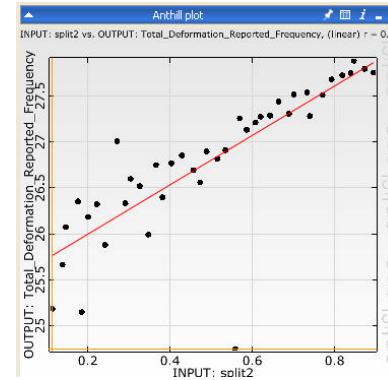
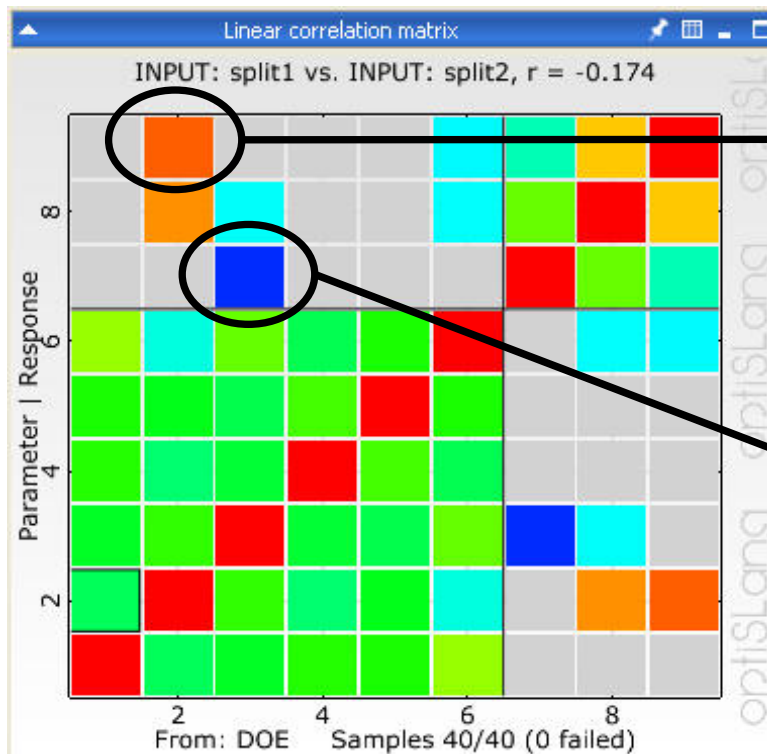


2. Define number of samples

Robust Design Optimization

Robust Design Optimization with „optiSLang inside Workbench“

Step 1: Sensitivity Analysis - Results



Stress:

88 %

Deformation:

84 %

Frequency:

80 %

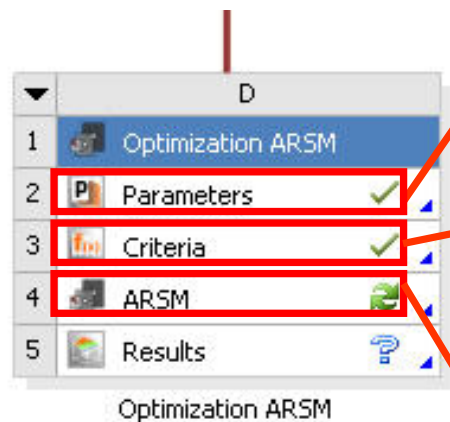
→ Important parameters:

split2, split3, split6

Robust Design Optimization

Robust Design Optimization with „optiSLang inside Workbench“

Step 2: First Optimization



Parameter setting

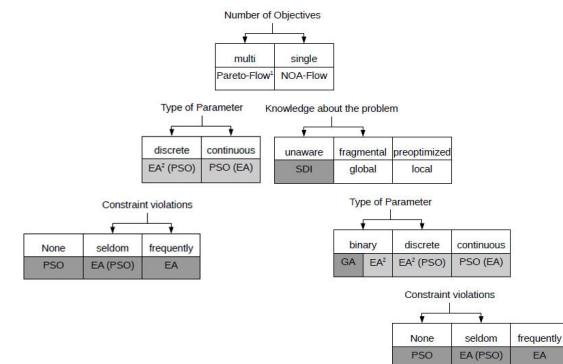
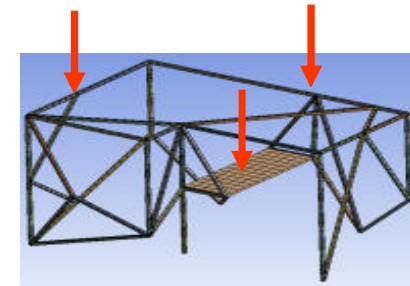
Define constraints & objectives:

$$\sigma < 43.5$$

$$d < 0.17$$

frequency \rightarrow max

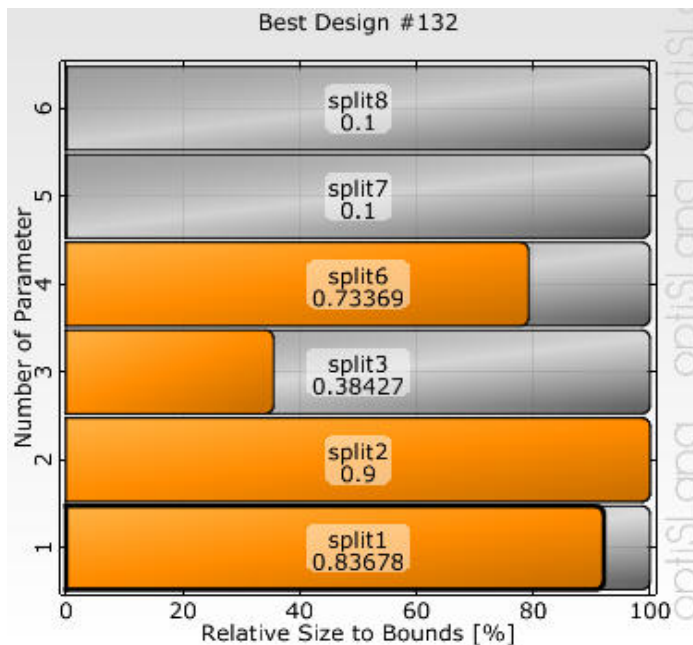
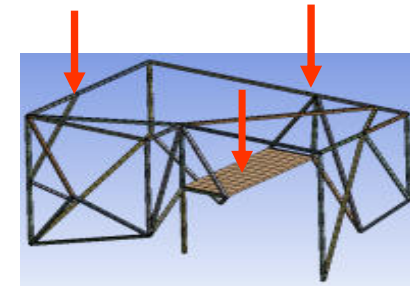
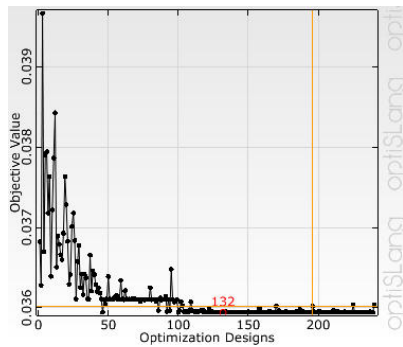
Just choose an algorithm.
The ,decision tree‘ helps!



Robust Design Optimization

Robust Design Optimization with „optiSLang inside Workbench“

Step 2: First Optimization - Results

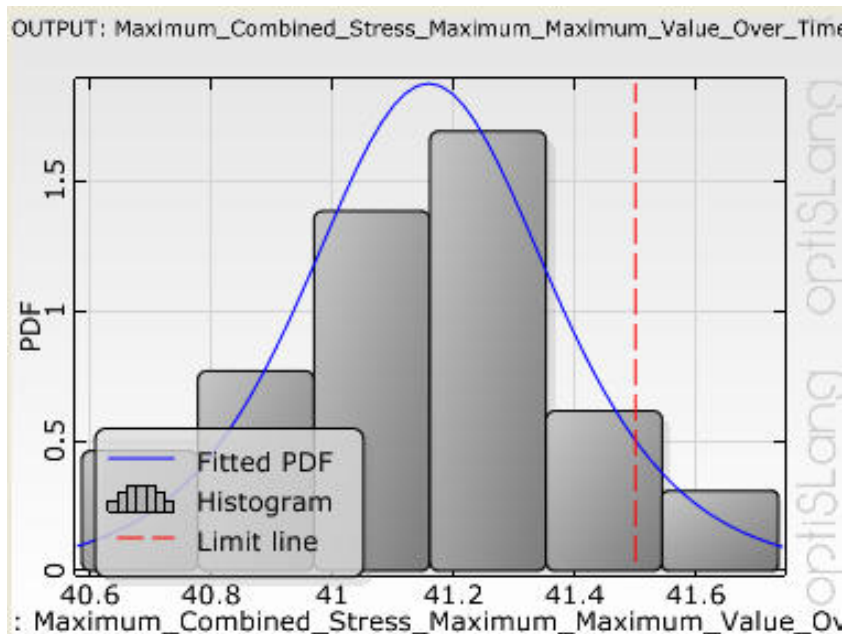


Stress = 40.87 < 41.5 (limit) ✓
Deformation = 0.169 < 0.17 (limit) ✓
1st Frequency = 27.9

Robust Design Optimization

Robust Design Optimization with „optiSLang inside Workbench“

Step 3: Robustness Evaluation with optimized design



The current sigma level for this design is: $(41.5-41.16)/0.242 = 1.4$

→ not good enough

Robust Design Optimization

Robust Design Optimization with „optiSLang inside Workbench“

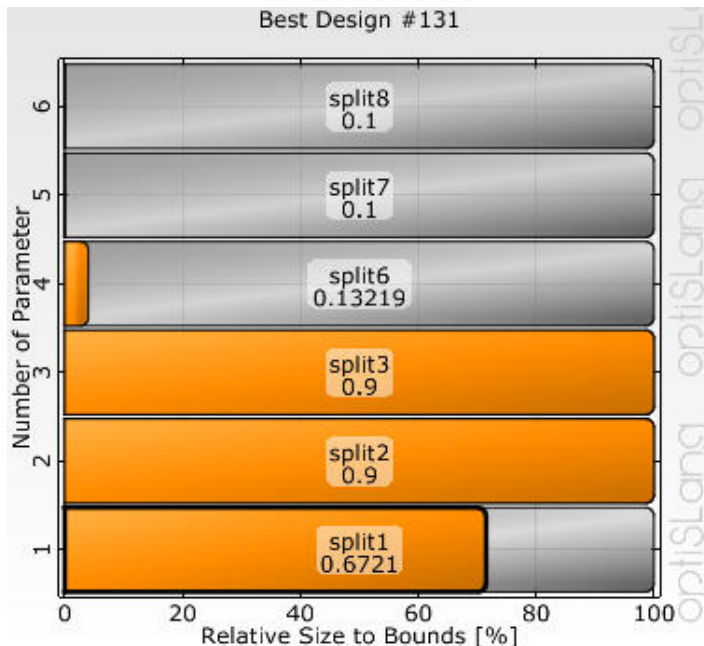
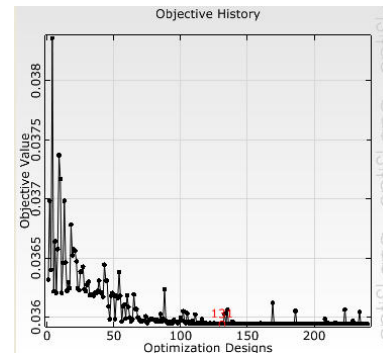
Step 4: Second Optimization with changed constraint

Define new stress constraint:

$$\sigma < 41.2$$

$$d < 0.17$$

frequency \rightarrow max

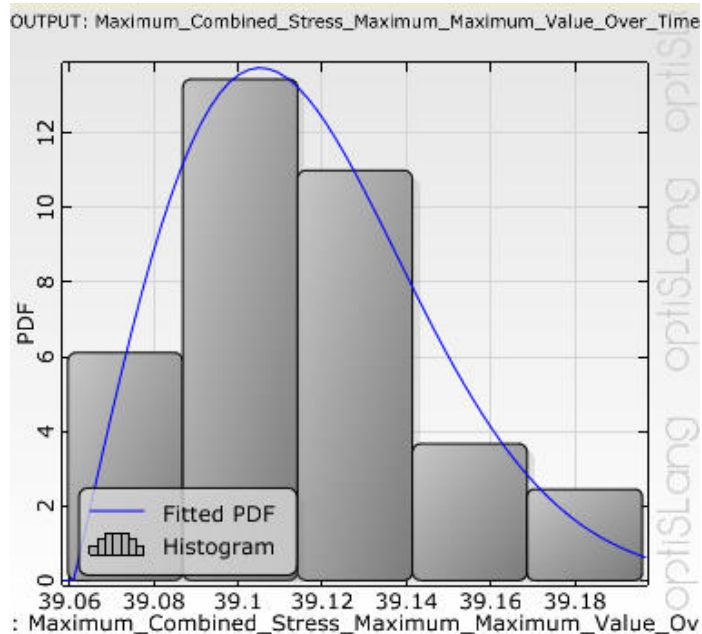


Stress = 39.0 < 41.5 ✓
Deformation = 0.168 < 0.17 ✓
1st Frequency = 27.8

Robust Design Optimization

Robust Design Optimization with „optiSLang inside Workbench“

Step 5: Robustness evaluation with second optimized design



Now, the sigma level is $> 2\sigma$

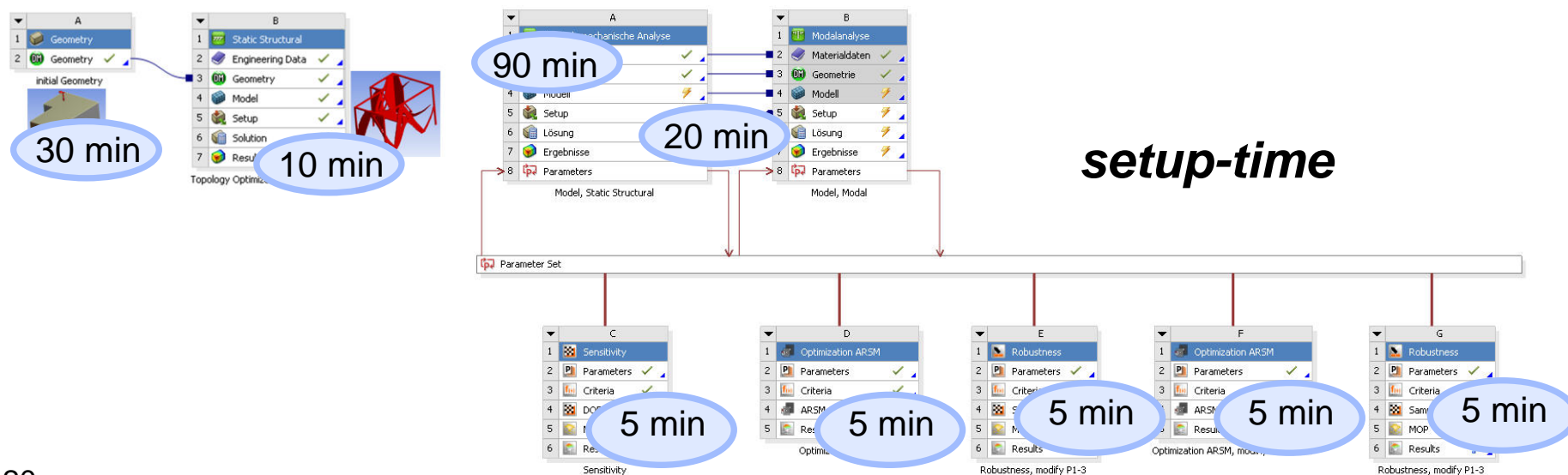
→ **ok!** optional: 3rd run with interpolated stress-

constraint

Robust Design Optimization

Conclusion

- Topology Optimization good for finding a concept
- Parametric Optimization good to work with manufacturable parameters and in more than 1 physics domain
- Robust Design Optimization can now be done inside Workbench in a very quick way: „optiSLang inside Workbench“
- easy-to-use tool, that saves time for the user:



Robust Design Optimization

Thanks for your attention!

