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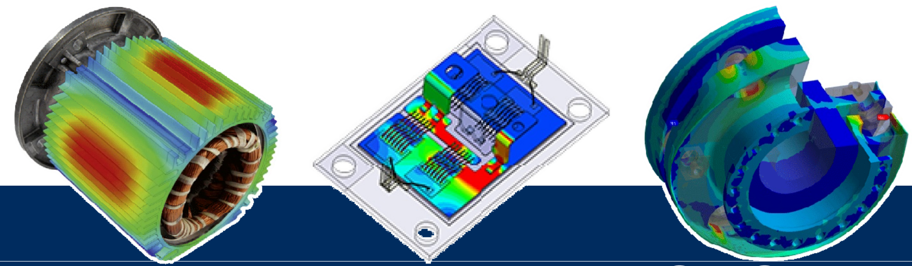

Parametric modeling and process simulation with ANSYS and optiSLang in additive manufacturing

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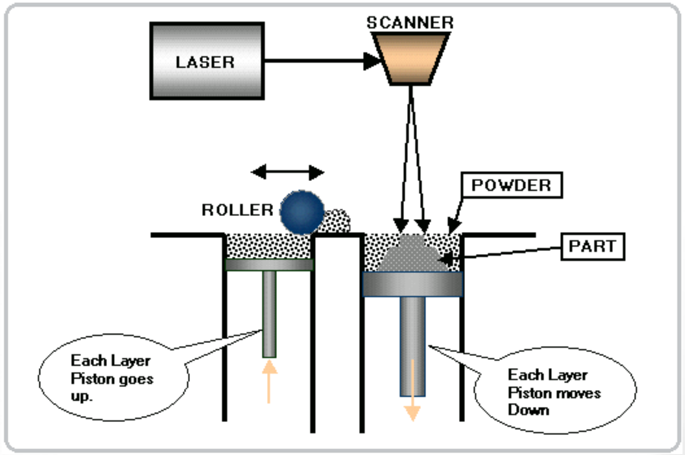
Weimarer Optimierungs- und Stochastiktage 21.-22.06.2018

Topics

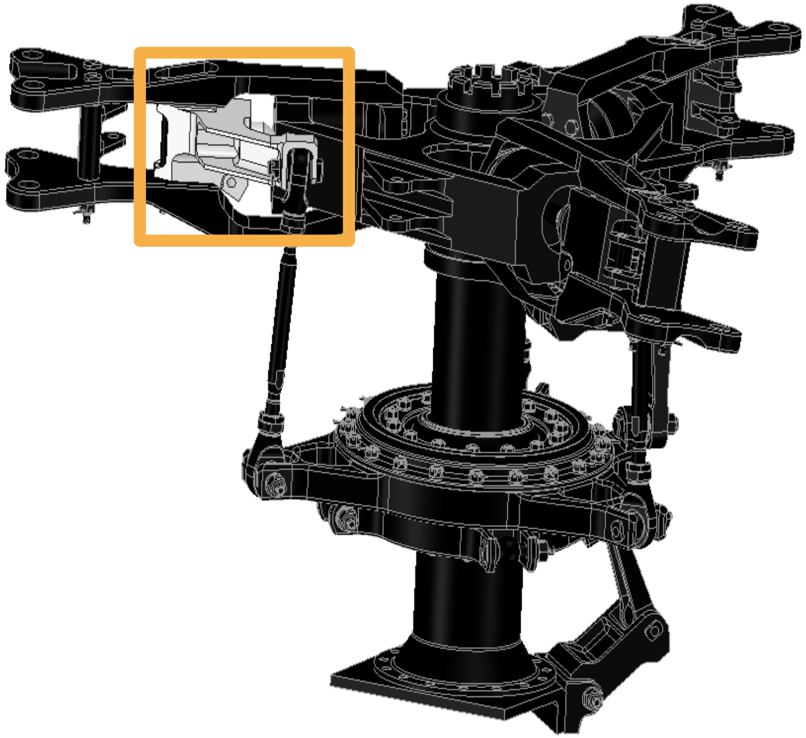
- Overview Additive Manufacturing
- ANSYS AM Process – from topology optimization to process simulation
- Why do we use topology optimization
- ANSYS Additive Suite – a parametric workflow for process simulation
- Connecting optiSLang to the additive simulation
- Summary

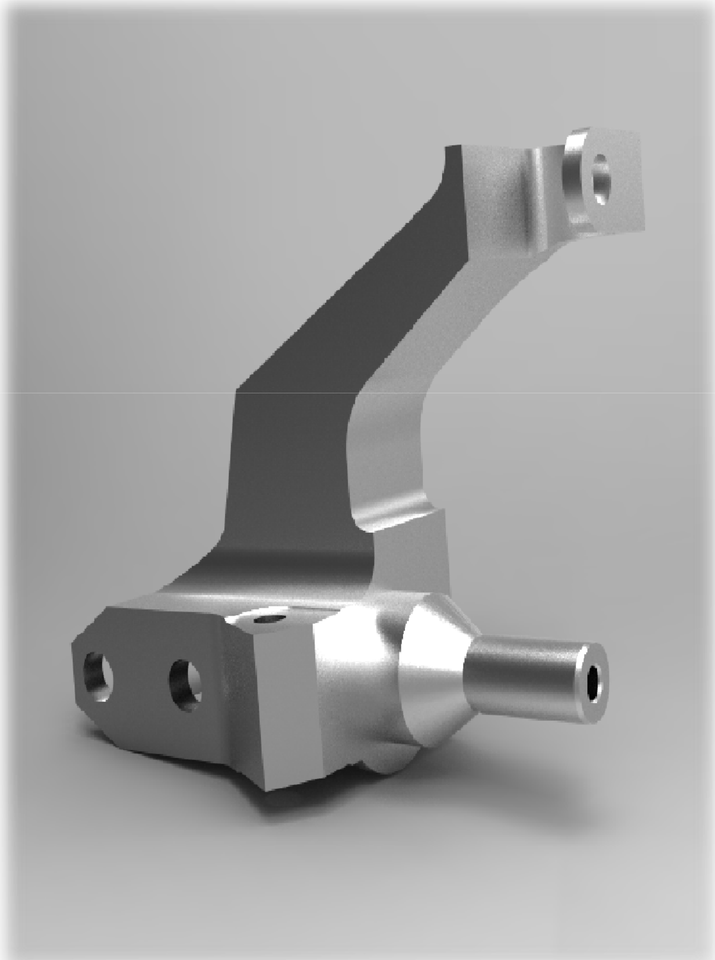
Additive manufacturing: From disruption to meta-materials



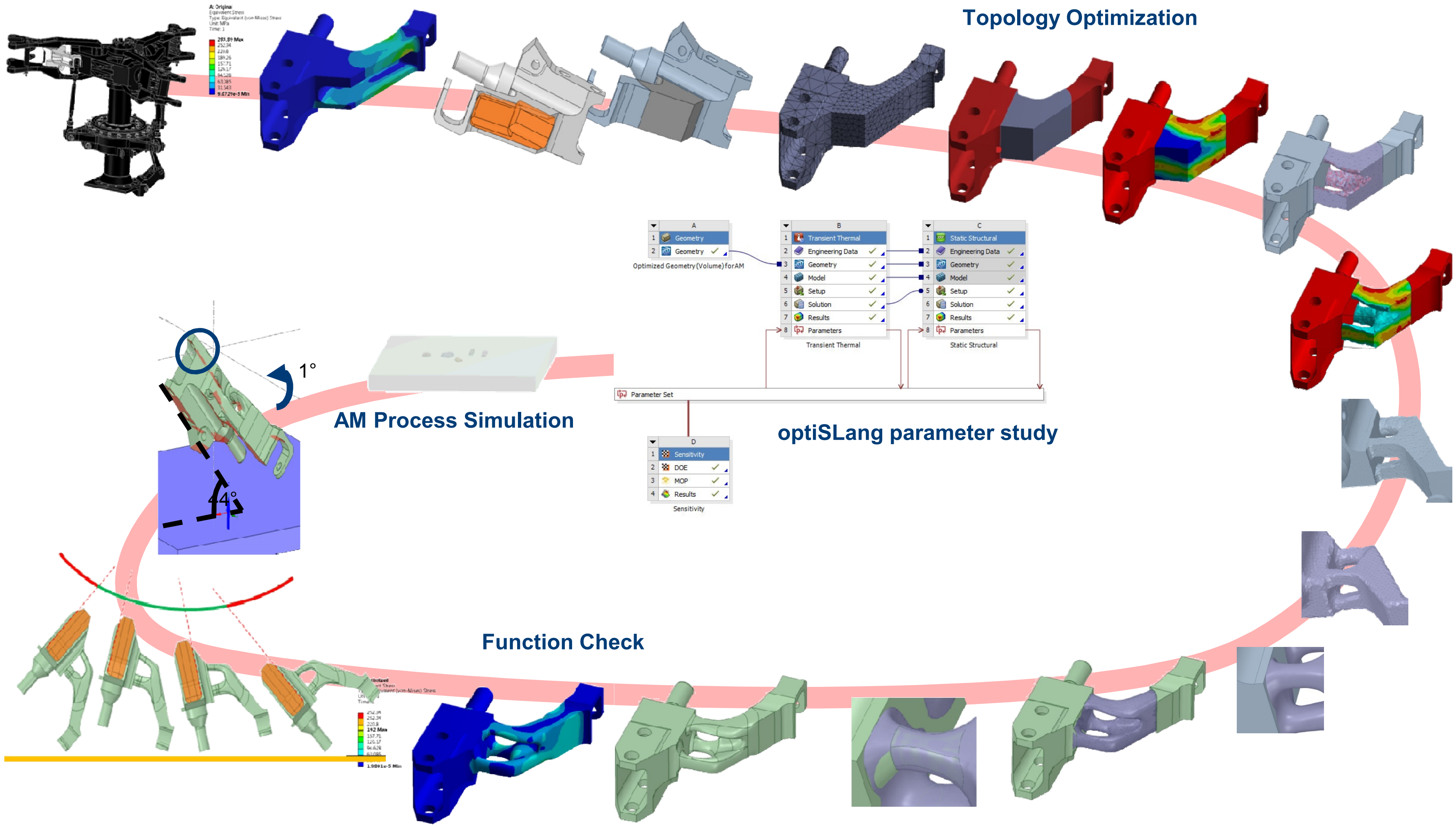
Task

- Optimization of a pitch arm from a helicopter rotor head



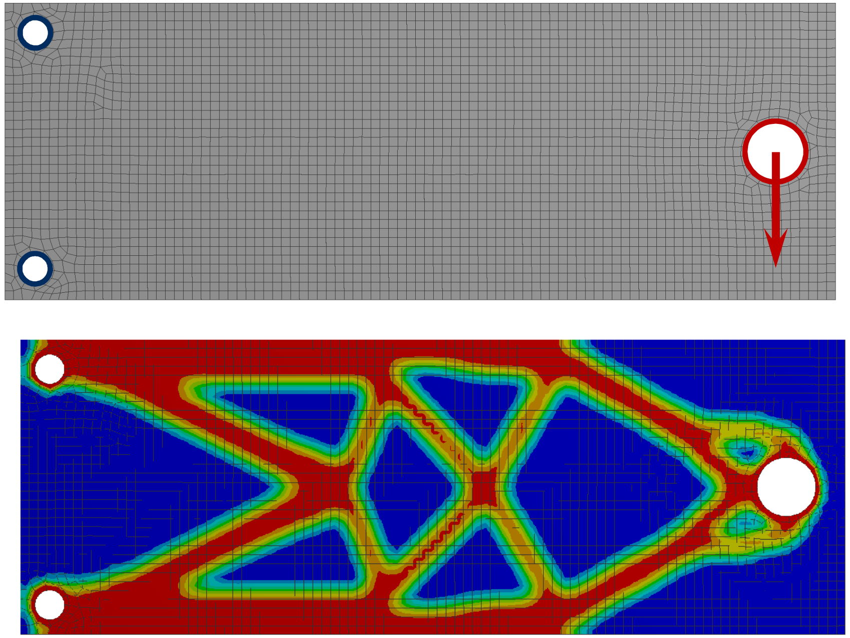


Overview: ANSYS AM Process



Why do we use topology optimization?

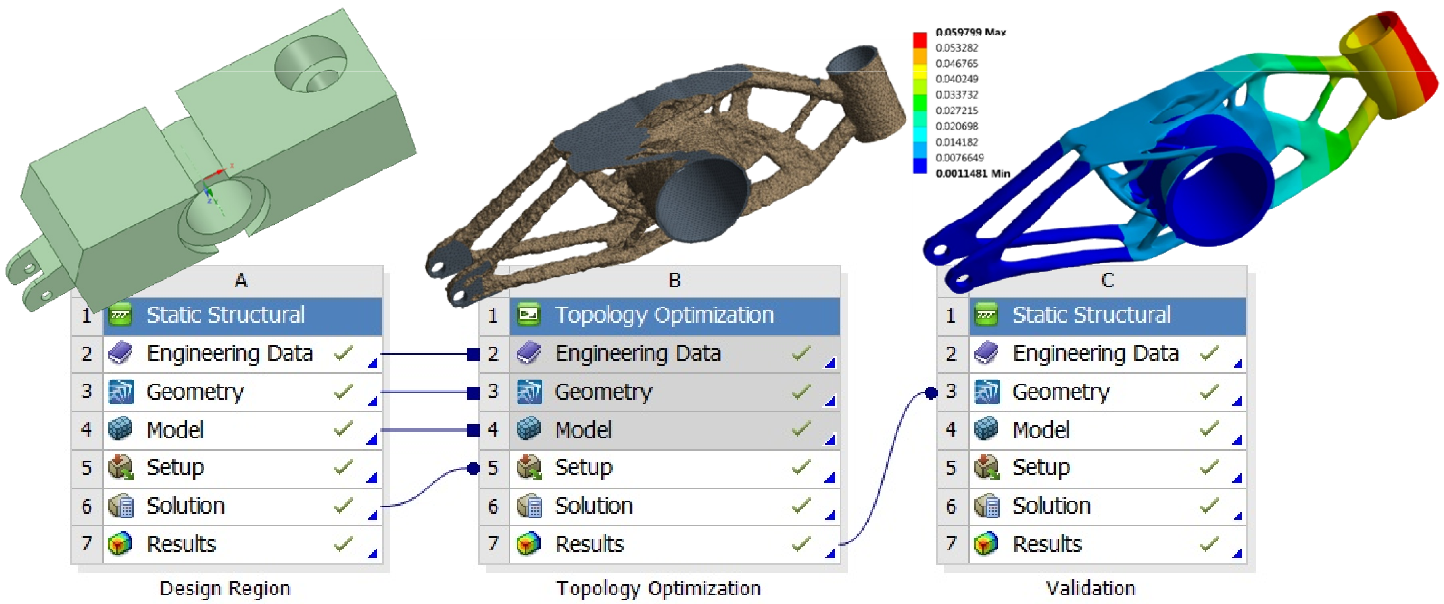
- The ANSYS topology optimization leads to a load case driven design.



- Features
  - physics-driven part design
  - Use of new manufacturing possibilities
  - Potential for lightweight structures and cost reduction

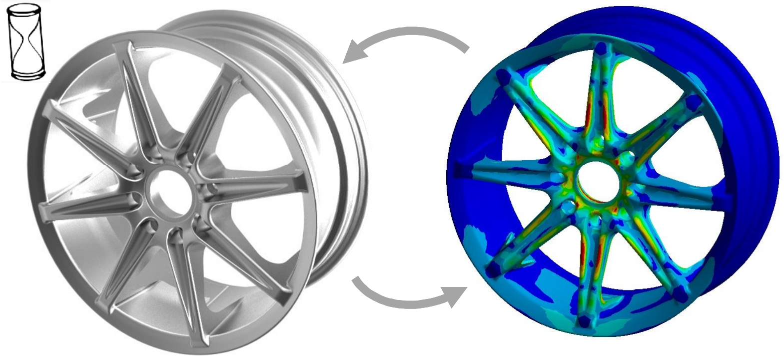
Workflow – a brief overview

- Use just 3 steps to an optimized design
  - Basic analysis (static, temperature or modal)
  - Topology optimization
  - Validation using the base simulation

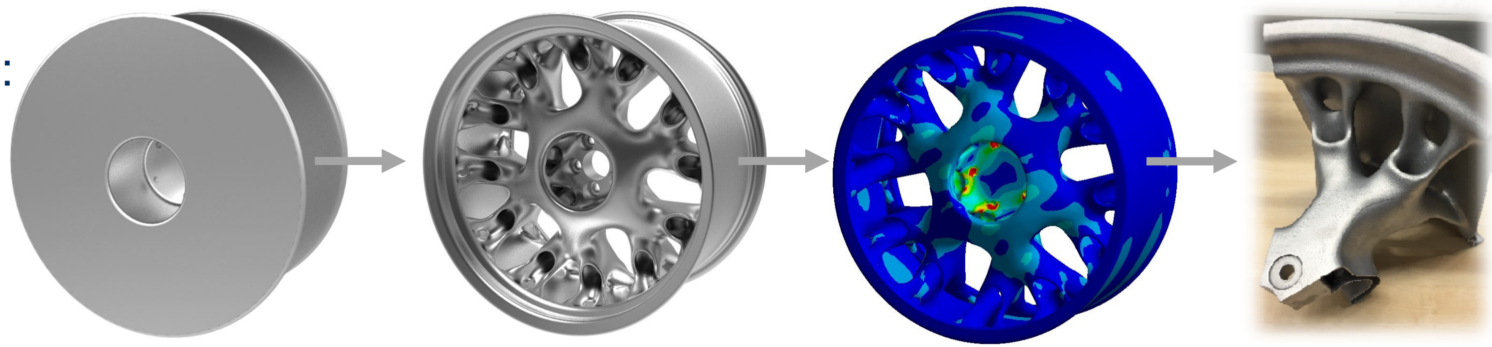


New ways in the designing process

- The use of additive manufacturing allows the realization of completely new designs
- Less manufacturing constraints will simplify the developing process and lead to more innovative products
- Traditional:



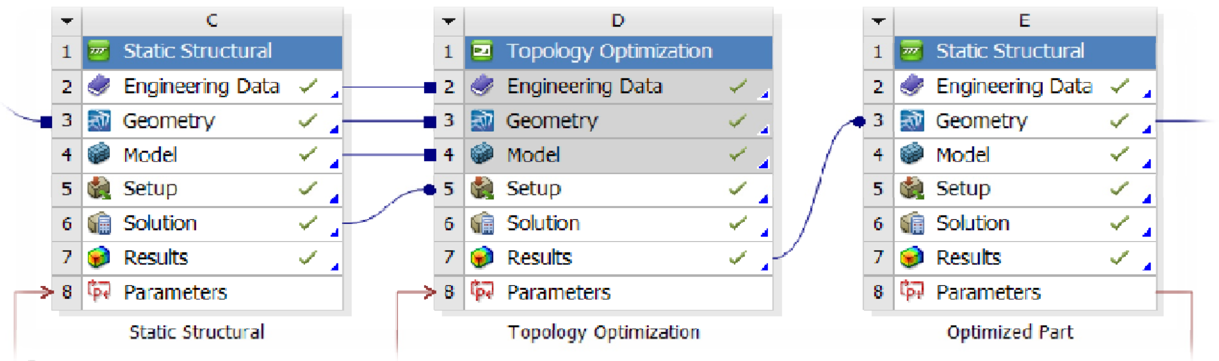
- Innovative:

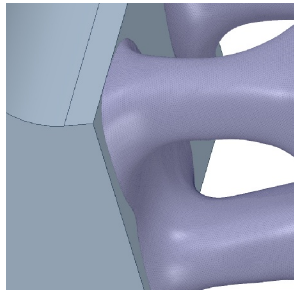


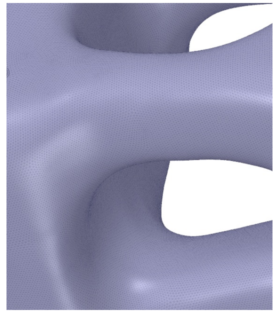
In Coorparation with Audi AG

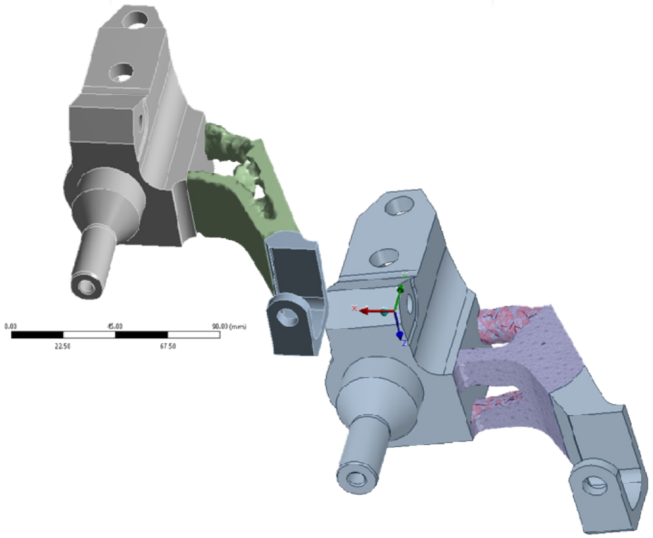
Technische Hochschule Ingolstadt

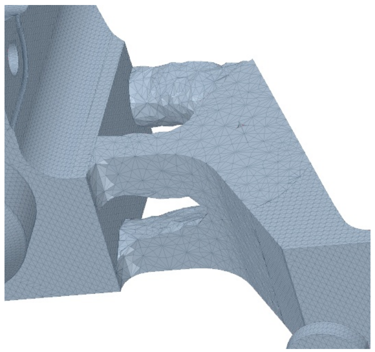
STL Preparation for Additive Manufacturing

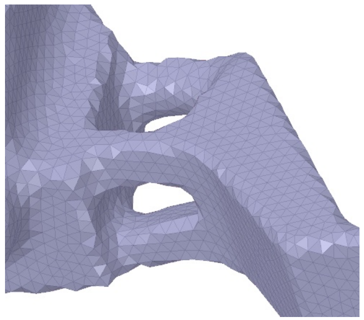


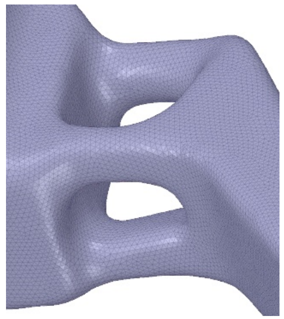












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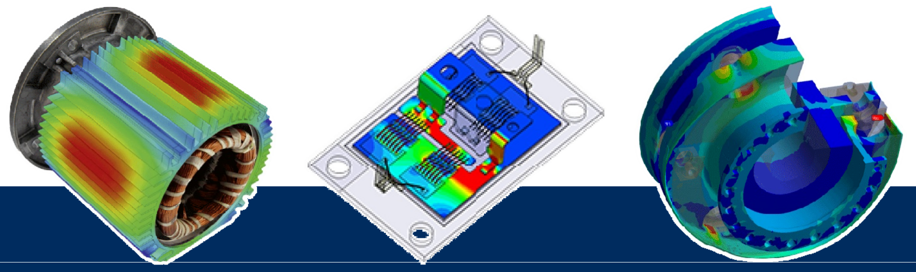
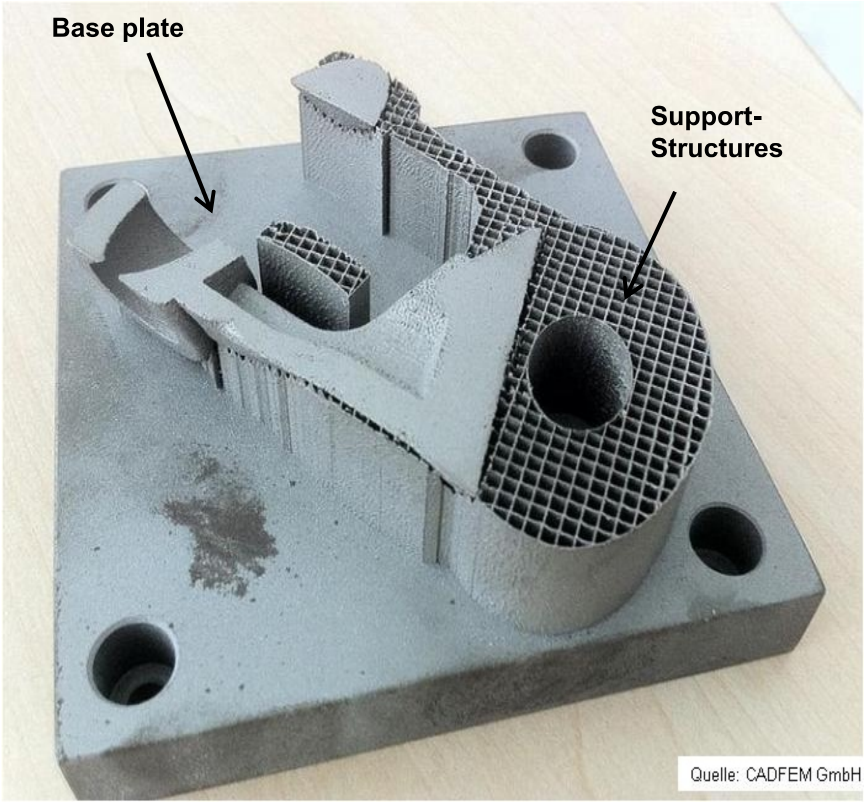


ANSYS Additive Suite

Workbench Additive Capabilities / Mechanical Additive Process Simulation (MAPS)

Additive manufacturing – why do we need a process simulation?

- Which challenges could occur using additive manufacturing?
  - High internal stress in the part and between part and base plate.
  - Occurance of cracks and unwanted deformation during the process.
  - Possibility of a blocking coater during the application of the powder layer (displacement of the blade: 0,01..0,05 mm)
  - Deformation and internal stress that occur after detaching the part from the baseplate can have a negative impact on the usability and the durability of the part.



Additive manufacturing – process simulation - goals

- The process simulation has the purpose …
  - … understanding the process itself because experiments like measuring the temperature during the process are not that simple.
  - … predict the process like setting process parameters, ensure process reliability, displacement, cracks
  - … predict the results – the product (displacement or internal stresses)

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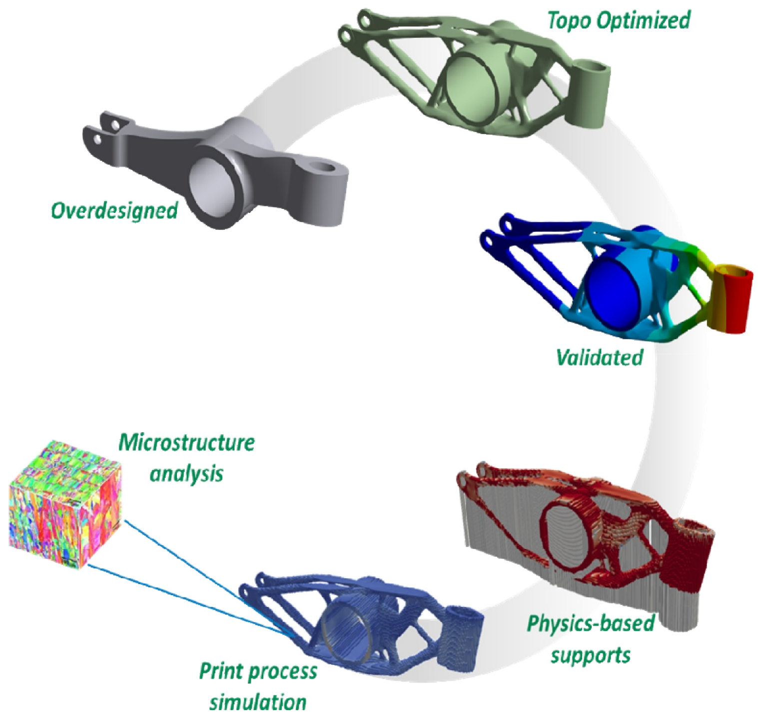
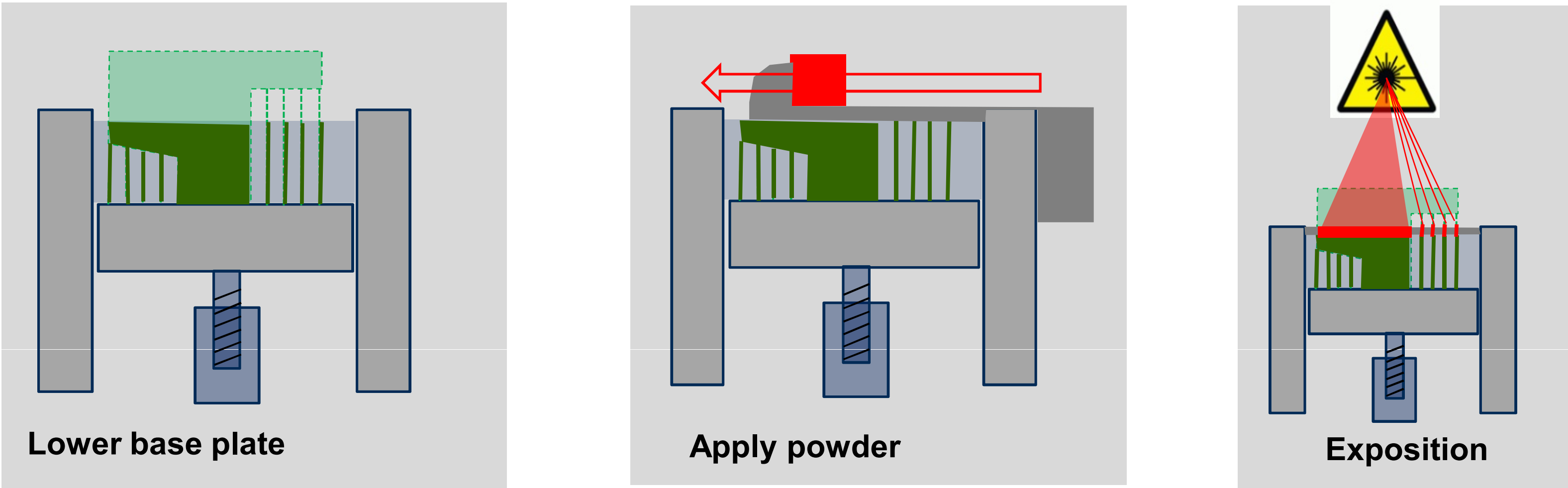
ANSYS Additive Suite

- Includes all ANSYS AM capabilities
- ANSYS Workbench & Mechanical Enterprise Additive Capabilities
  - Process Simulation
  - Topological Optimization
  - Lattice Optimization
- Additive Science
  - Scan-vector-level thermal analysis
  - In-depth material behavior
- Additive Print

- FEA analysts, AM experts and material researchers
- Industry leading analysis tool for AM processes and materials



Additive manufacturing – process simulation



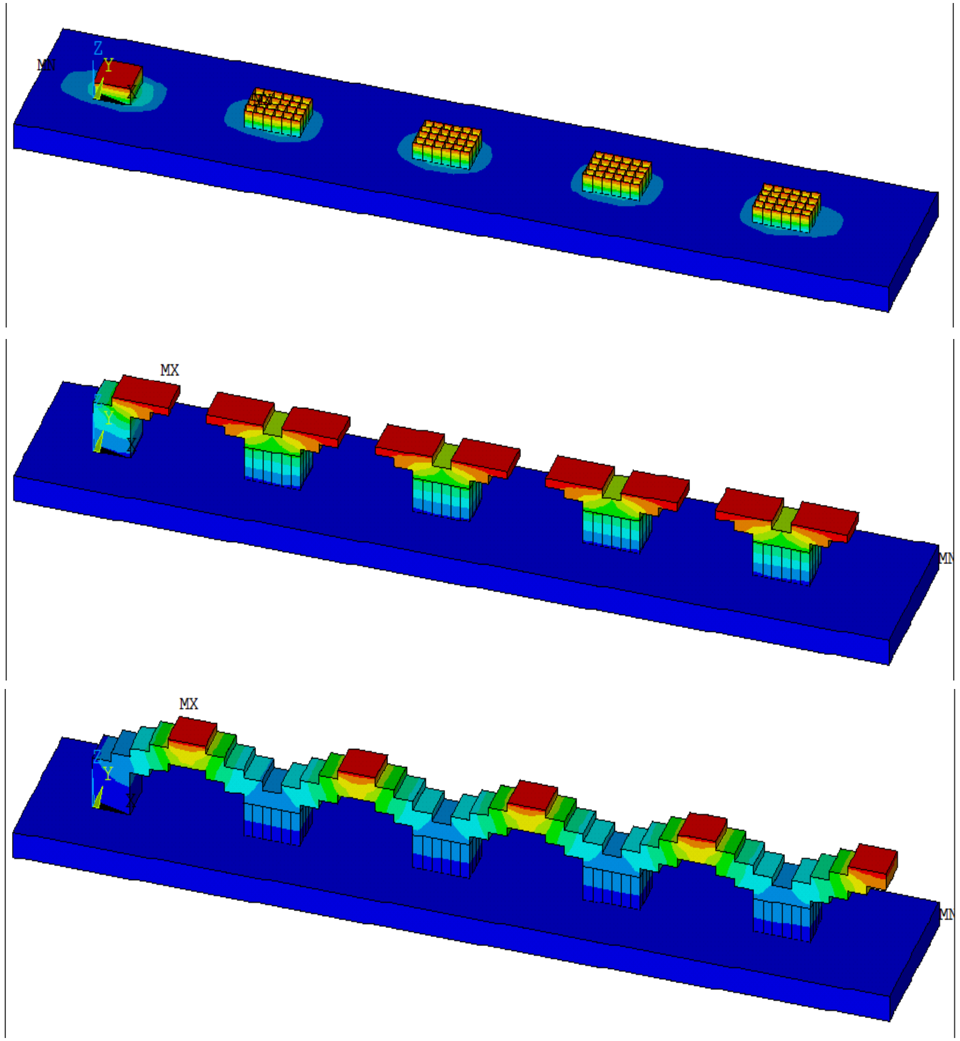
Additive manufacturing :

In our case a creation of parts made of metal powder that has been applied in layers and melted by a laser beam.

Additive manufacturing - simulation in ANSYS

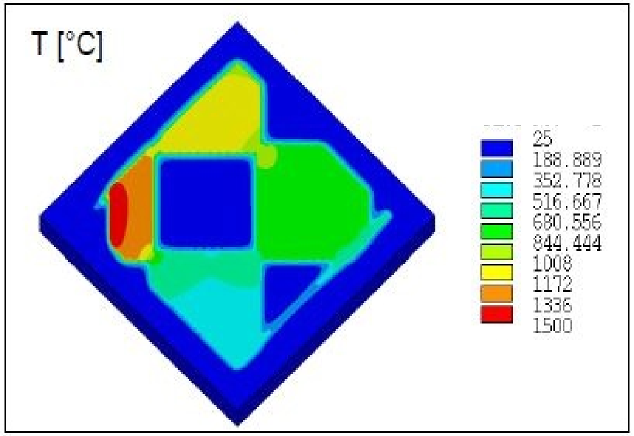
Simulations model

- Creating the FE-model layerwise including the support structures.
- Several manufacturing layers are merged to a „simulation layer“ with a thickness of e.g. 1mm
- Applying the temperature layerwise.
- Activation and deactivation of element layers.
- Possibility to include effects of microstructural transformation.

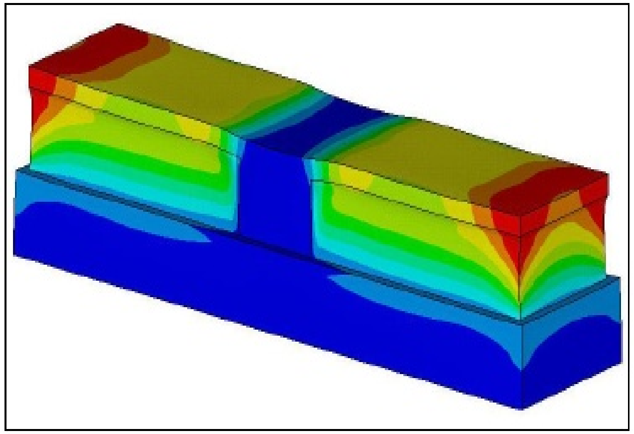


Additive manufacturing - simulation in ANSYS

- Challenges in the simulation:
  - Local discretization: layerwise structures and dimensions (Laserspot diameter in µm range while the parts have a dimension in cm range).
  - Time discretization: Process time (Exposition of single layers in ms range while the entire process is in h range)
- Solution approach:
  - Simulation of the layers in a **detail model**
  - Simulation of the entire part in a **global model**



Detail model



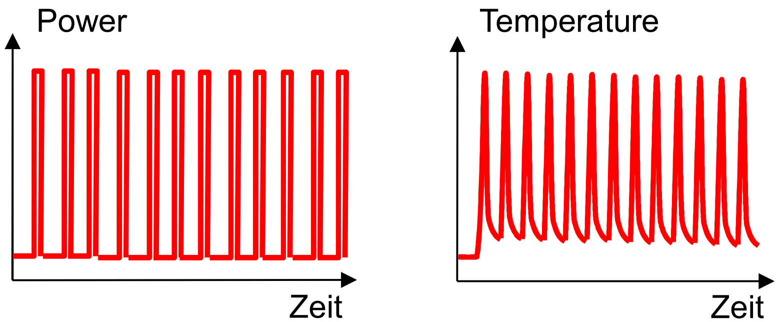
Global model

Lumped Layer Approach – The way used in ANSYS AM

- Global model heat source
- Applying the power by using temperature T

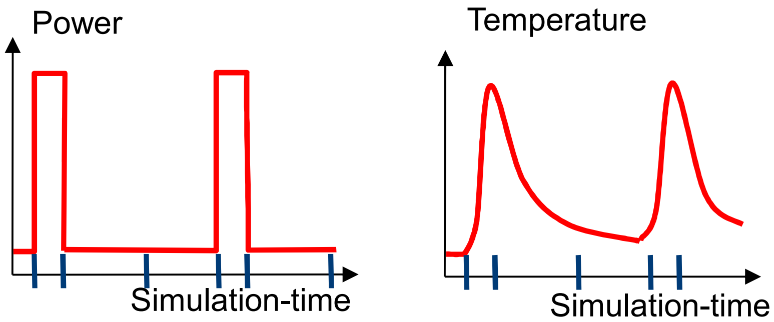
Reality:
Power (Time)
Temperature (Time)

1 layer:	Q, Δt	E = Q • Δt
100 layers:	Q, Δt	E = 100 • Q • Δt

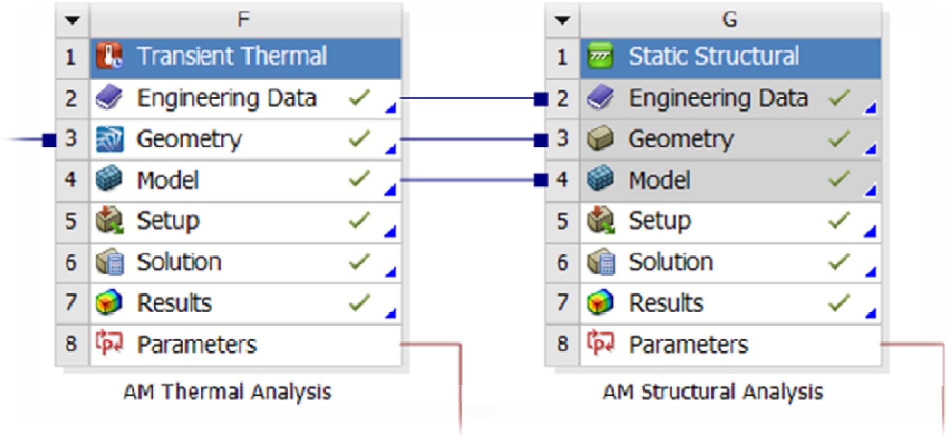


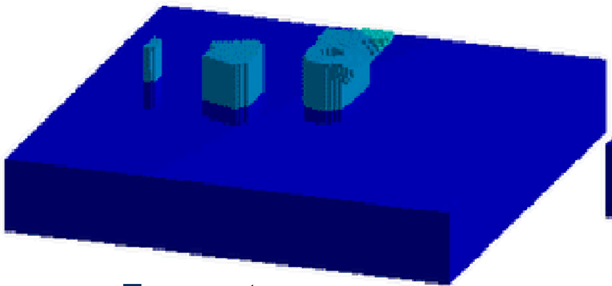
Simulation (ANSYS):
Power (Time)
Temperature (Time)

1 layer:	ΔT	E = ΔT • V • c • ρ
2 layers:	ΔT	E = 2 • ΔT • V • c • ρ

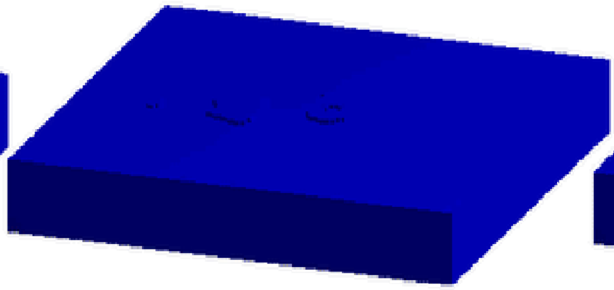


ANSYS Mechanical Additive Process Simulation

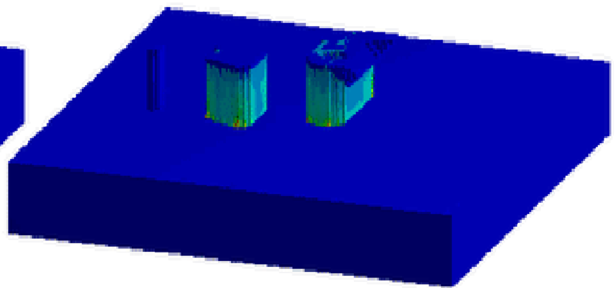




Temperature

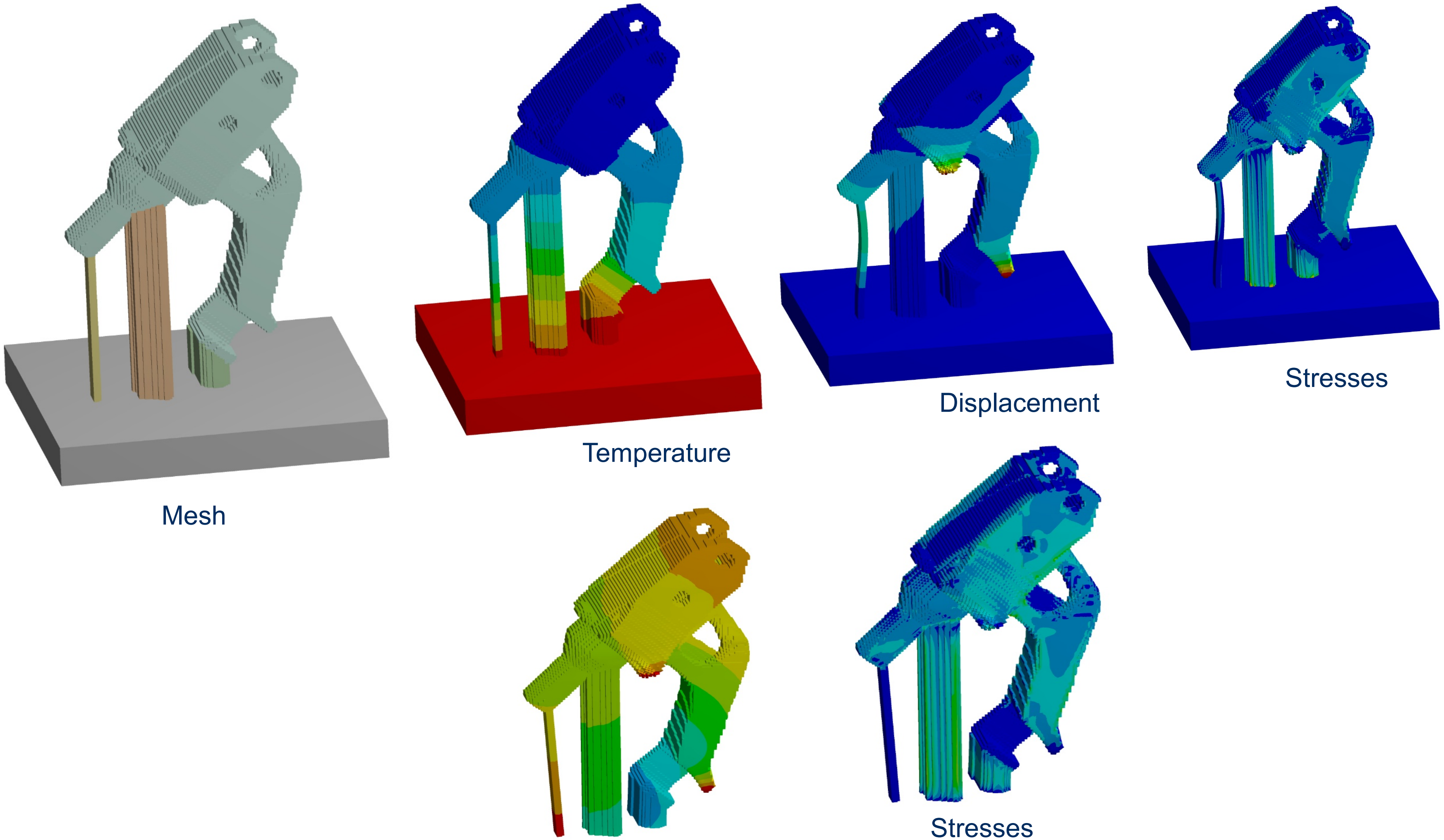


Displacement



Stress

ANSYS Mechanical Additive Process Simulation



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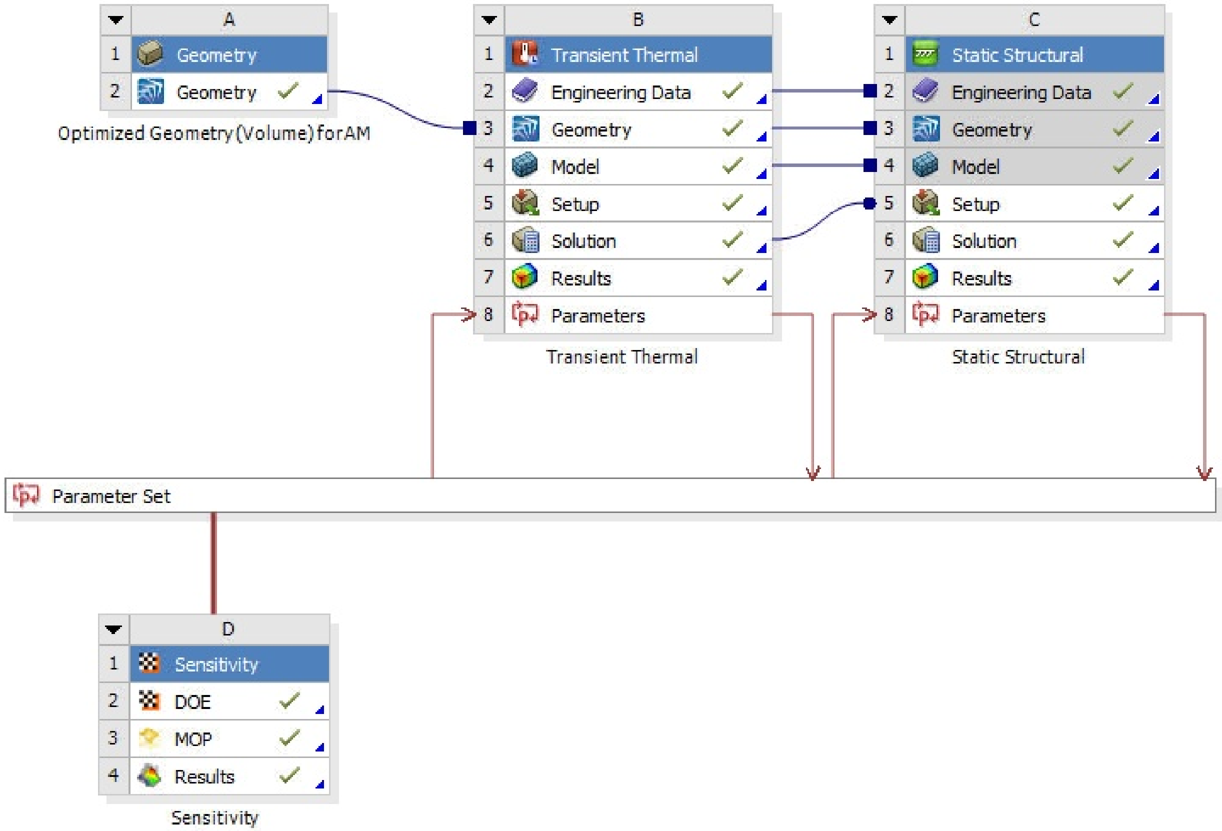
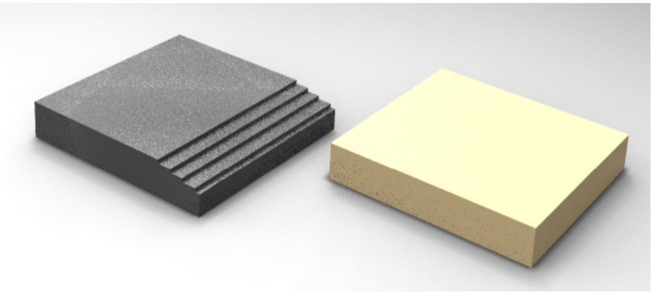
Parametrization of the process simulation

- Fully integrated and parametrized process simulation using ANSYS optiSLang

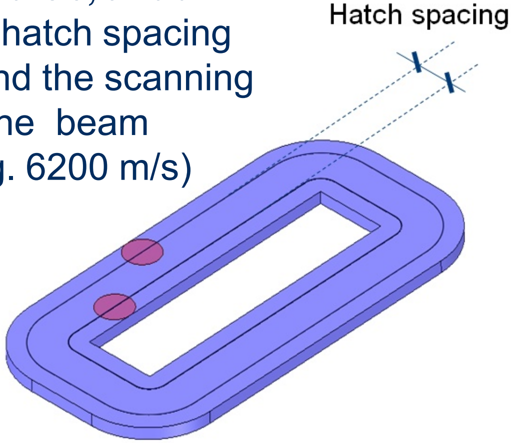


Examples for parametrization of the process simulation

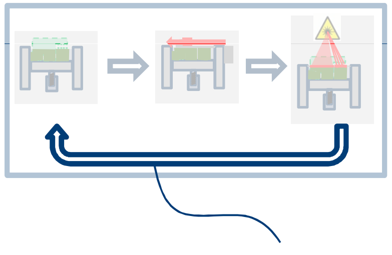
- ***ambuild****,layert,0.045*
  This is the depostion layer thickness that is used in the PBF process (not the Finite Element thickness)



- ***ambuild****,scan,0.36,6200*
  This defines the hatch spacing (e.g. 0.36mm) and the scanning speed which is the beam travel speed (e.g. 6200 m/s)



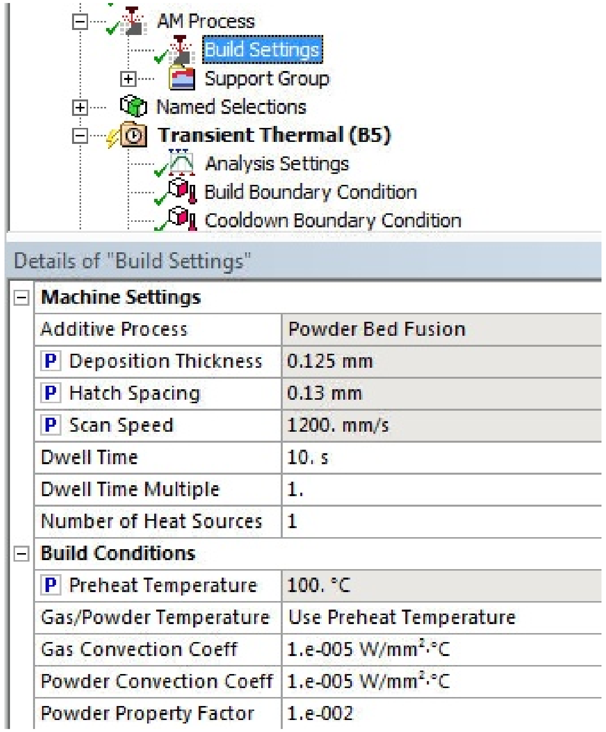
- ***ambuild****,time,10*
  Here you can define the inter-layer dwell time. This is the time it takes from the end of the deposition of a layer to the start of the deposition of the next layer (e.g. 10s).
  This includes e.g. the time it takes to reposition the recoater and to spread a new powder layer



- ***ambeam****,1*
  Number of used laser beams
- ***amenv****,50.0,0.01*
  Temperature and convection coefficient of the enclosure gas
- ***ampowder****,70.0,0.01,0.01*
  Temperature and convection coefficient of the added powder

Parametrize the AM process

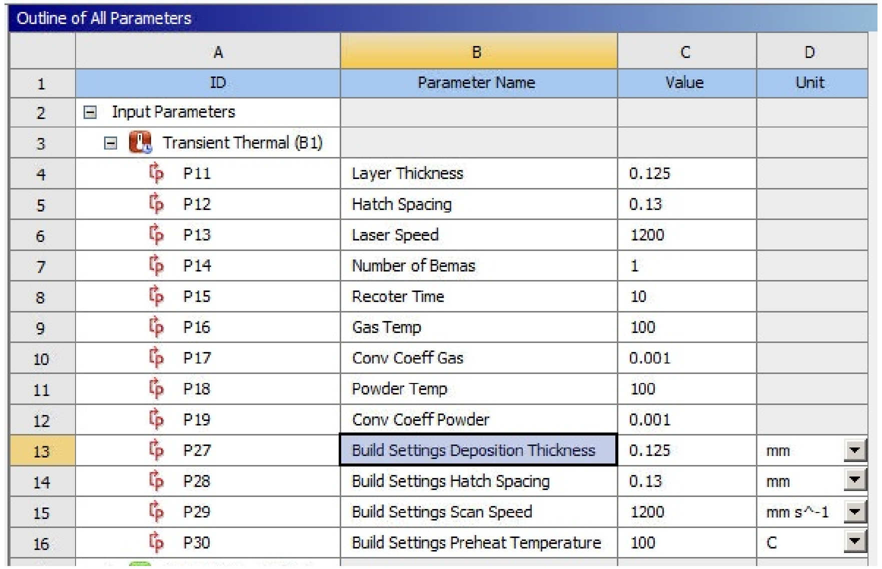
- Some parameters are directly parametrizable in ANSYS Workbench just by clicking in the checkbox:



Machine Settings	
Additive Process	Powder Bed Fusion
P Deposition Thickness	0.125 mm
P Hatch Spacing	0.13 mm
P Scan Speed	1200. mm/s
Dwell Time	10. s
Dwell Time Multiple	1.
Number of Heat Sources	1
Build Conditions	
P Preheat Temperature	100. °C
Gas/Powder Temperature	Use Preheat Temperature
Gas Convection Coeff	1.e-005 W/mm²·°C
Powder Convection Coeff	1.e-005 W/mm²·°C
Powder Property Factor	1.e-002

- The included parameters are a good base for a first design study.

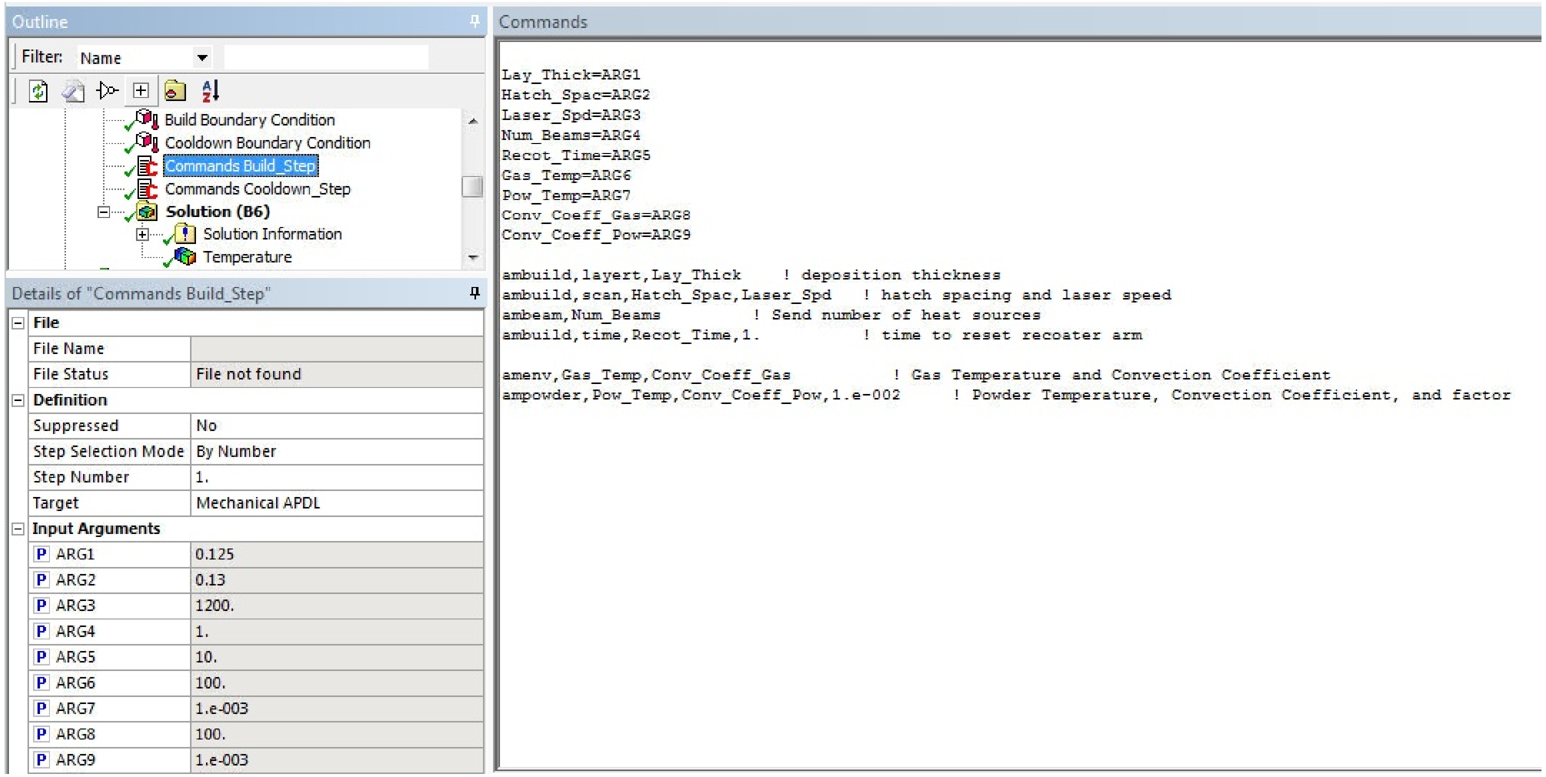
- Overview in in the parameter set


Outline of All Parameters

	A	B	C	D
1	ID	Parameter Name	Value	Unit
2	Input Parameters			
3	Transient Thermal (B1)			
4	P11	Layer Thickness	0.125	
5	P12	Hatch Spacing	0.13	
6	P13	Laser Speed	1200	
7	P14	Number of Bemas	1	
8	P15	Recoter Time	10	
9	P16	Gas Temp	100	
10	P17	Conv Coeff Gas	0.001	
11	P18	Powder Temp	100	
12	P19	Conv Coeff Powder	0.001	
13	P27	Build Settings Deposition Thickness	0.125	mm
14	P28	Build Settings Hatch Spacing	0.13	mm
15	P29	Build Settings Scan Speed	1200	mm s^-1
16	P30	Build Settings Preheat Temperature	100	C

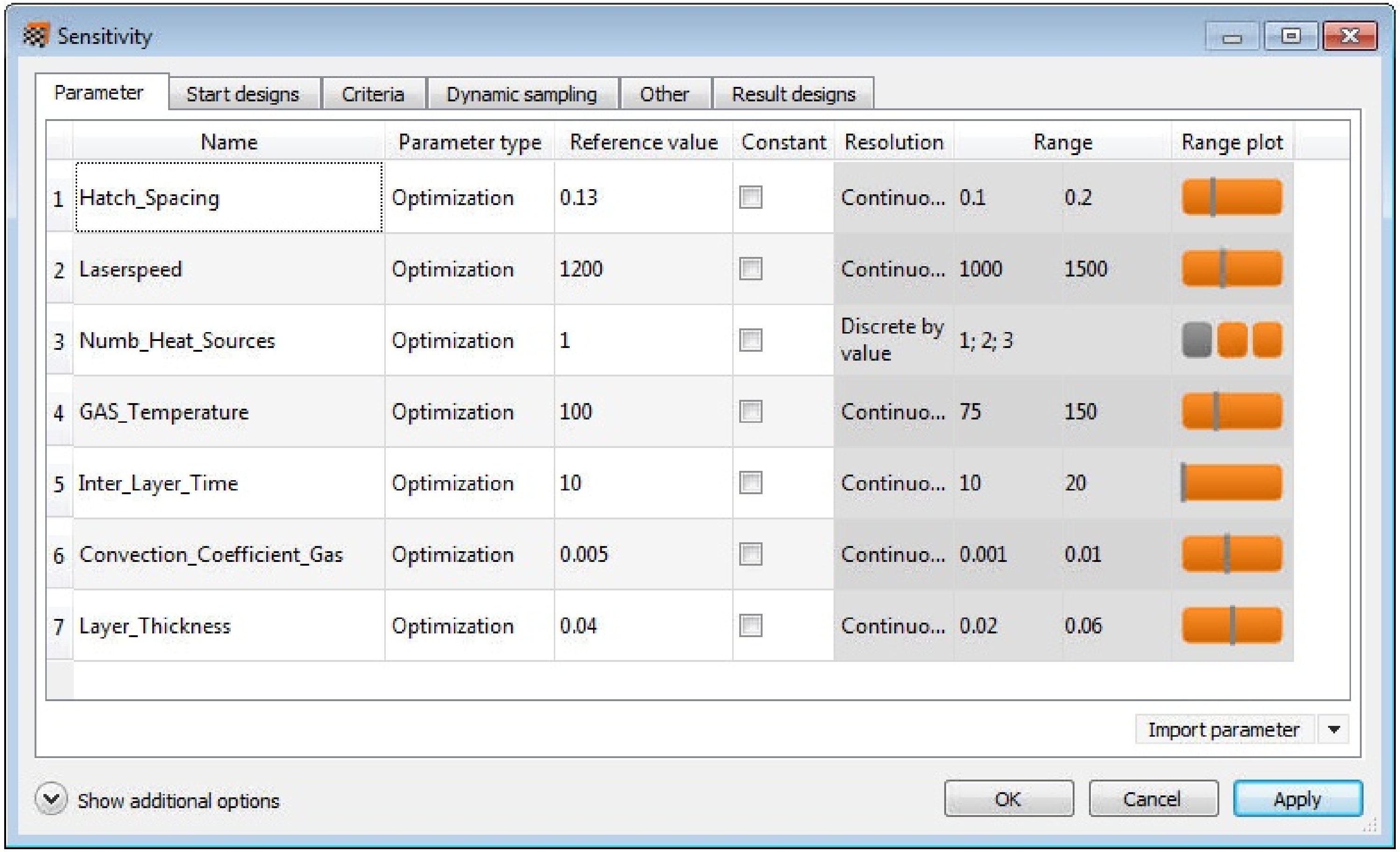
Parametrize the AM process

- Full parametrization possibilities by using some MAPDL commands
- Use this for a deeper sensitivity analysis and parameter identification



Sensitivity Study

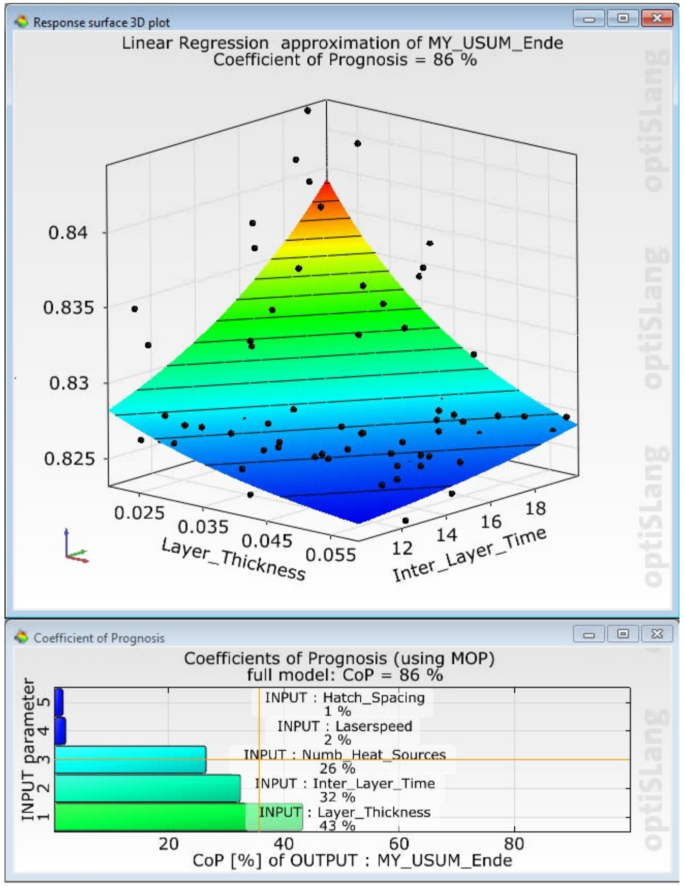
- Set up a quick sensitivity study using optiSLang inside ANSYS

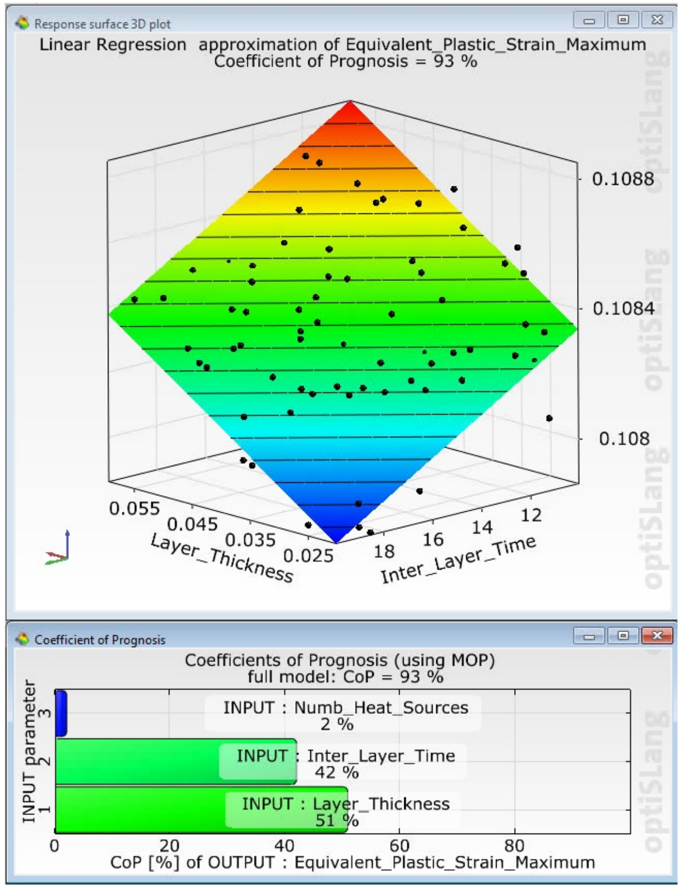


	Name	Parameter type	Reference value	Constant	Resolution	Range		Range plot
1	Hatch_Spacing	Optimization	0.13		Continuo...	0.1	0.2	
2	Laserspeed	Optimization	1200		Continuo...	1000	1500	
3	Numb_Heat_Sources	Optimization	1		Discrete by value	1; 2; 3		
4	GAS_Temperature	Optimization	100		Continuo...	75	150	
5	Inter_Layer_Time	Optimization	10		Continuo...	10	20	
6	Convection_Coefficient_Gas	Optimization	0.005		Continuo...	0.001	0.01	
7	Layer_Thickness	Optimization	0.04		Continuo...	0.02	0.06	

Sensitivity study

- Learn more about the parameter correlation and set up a base for your parameter identification to ensure a predicted AM process in ANSYS.

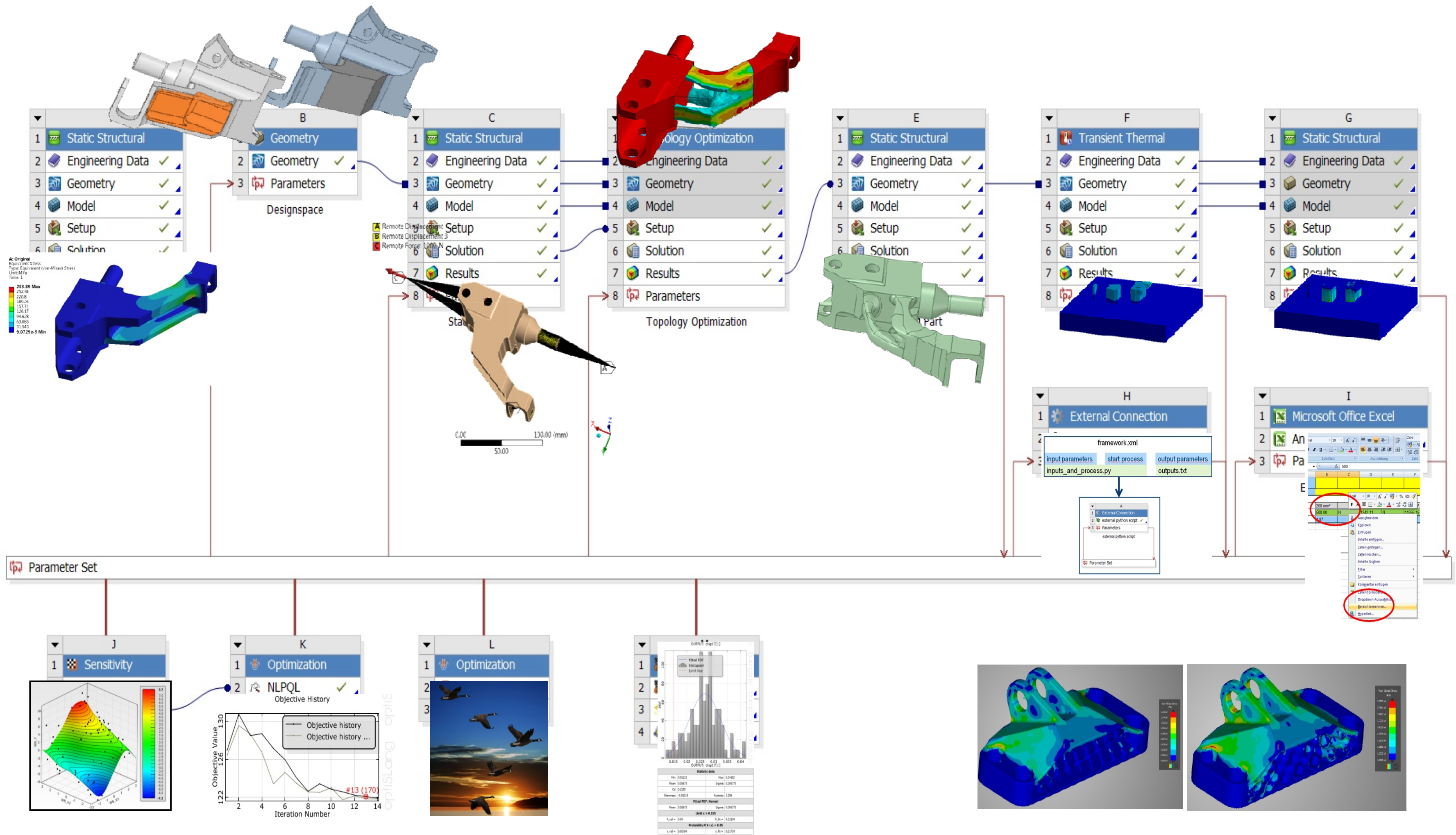




Summary

- The ANSYS topology optimization leads to a new way in the design process. The parts can now be designed just physics driven.
- Innovative designs often need to be manufactured additively.
- The ANSYS additive process simulation gives you a tool to simulate the build process of the manufacturing process to determine important results like deformations, internal stresses, strain and temperatures.
- The parametrized workflow in ANSYS using optiSLang will give you the correlation between the process parameters and the results.
  This is a base for a parameter identification to set up a process adjusted to your requirements.

Summary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Geometry
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Static Structural
Engineering Data
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Static Structural
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Model
Setup
Solution
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External Connection
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input parameters
start process
output parameters
inputs_and_process.py
outputs.txt
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Objective History
Objective history
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