Manufacturing the Future. Solve upcoming challenges with the help of simulation.

Presented By: Santhosh Nagaraju / LN Siva Sai
MSC Software

simufact
Simulating Manufacturing
MSC Software Company

PART OF HEXAGON

Simufact Product Portfolio

Cold Forming

Hot Forging

Sheet Metal Forming

Mechanical Joining

Rolling

Ring Rolling

Open Die Forging

Heat Treatment

Powder Bed Fusion

Arc Welding

Laser Beam

Electron Beam

Resistance Spot Welding

Brazing

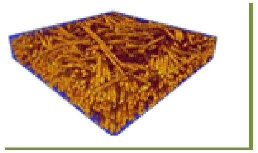
Stress Relief

Metal Deposition

Range of Simulations

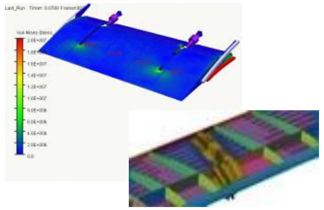
Materials | Parts | Manufacturing | Assembly | Systems

Materials



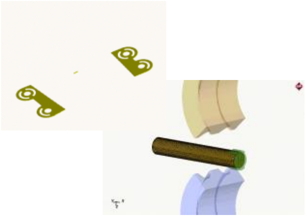
- Digimat
- Digimat-VA
- MaterialCenter

Parts



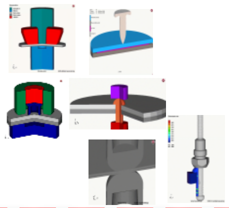
- MSC Apex
- Marc

Manufacturing



- Digimat Additive
- Simufact Additive
- Simufact Forming

Assembly



- Simufact Welding
- Simufact Joining

Systems

- sc/Tetra
- Patran
- scFLOW
- Adams
- MSC Apex
- AdamsCar - Realtime
- Nastran
- Actran

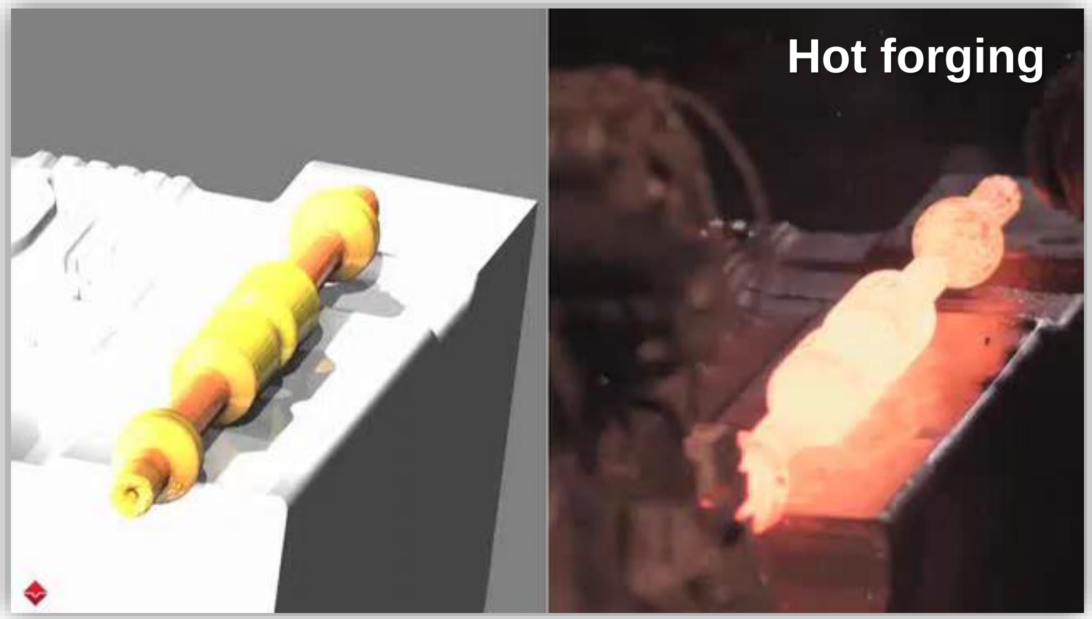
SimManager

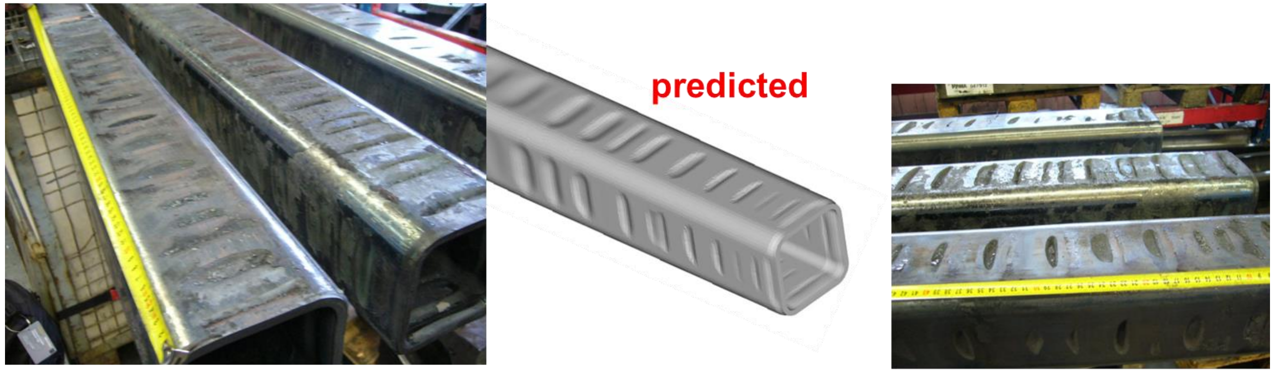
Hot Forming

Shift physical testing to virtual testing!

- Find suitable preform/intermediate shape design
- Avoid defects such as
  - Folds
  - under fillings

- Increased profitability by
  - Reduced scrap/waste material
  - Higher output
  - Better machine usage
  - Improved product quality



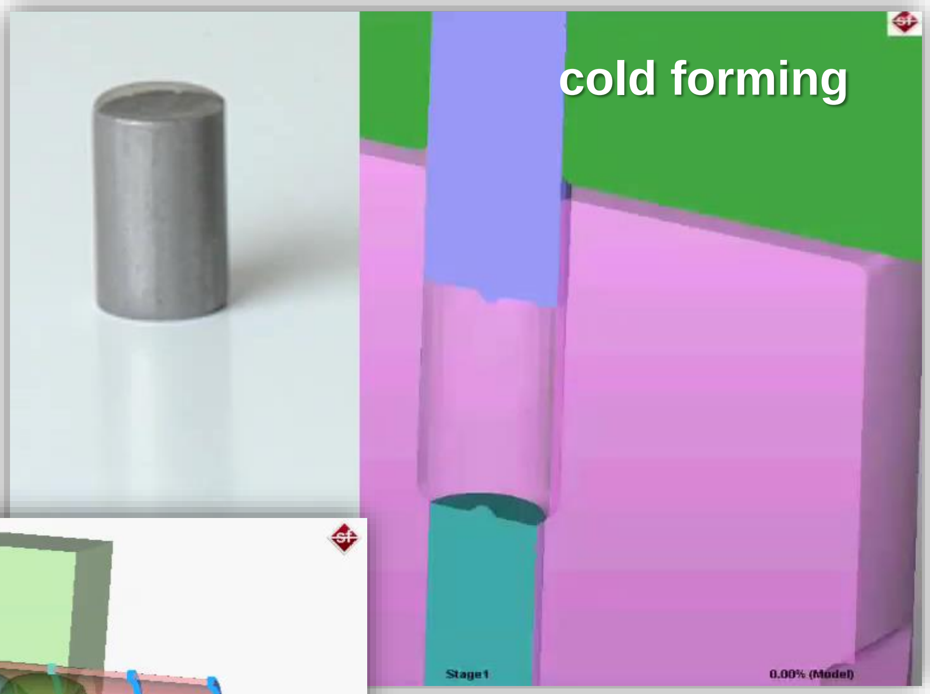


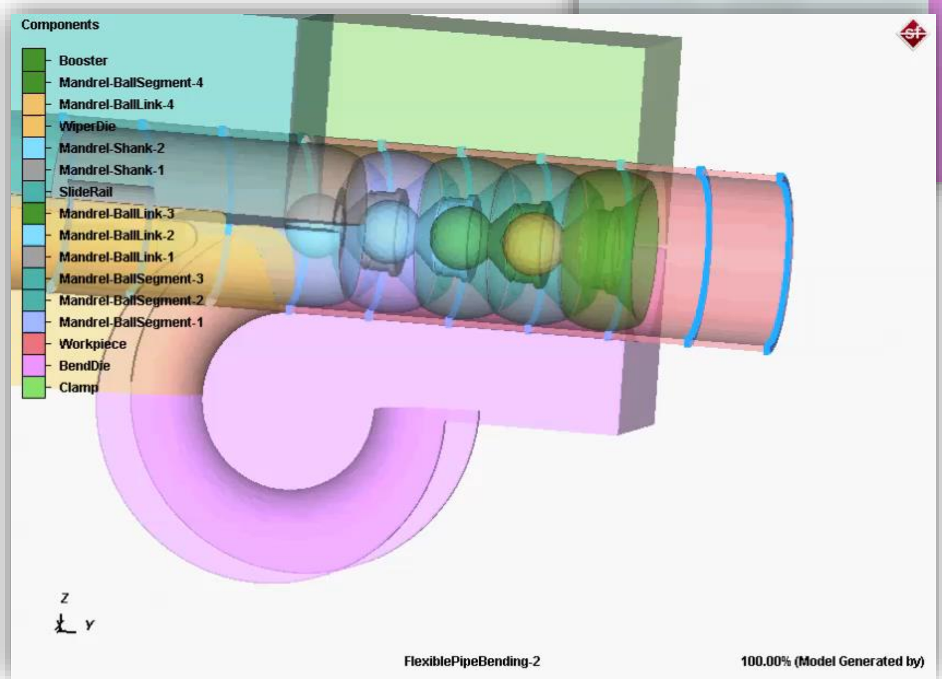
Cold Forming

Shift physical testing to virtual testing!

- Proof of stage design
- Avoid geometrical defects like
  - Folds
  - under fillings
- Avoid physical defects like cracks

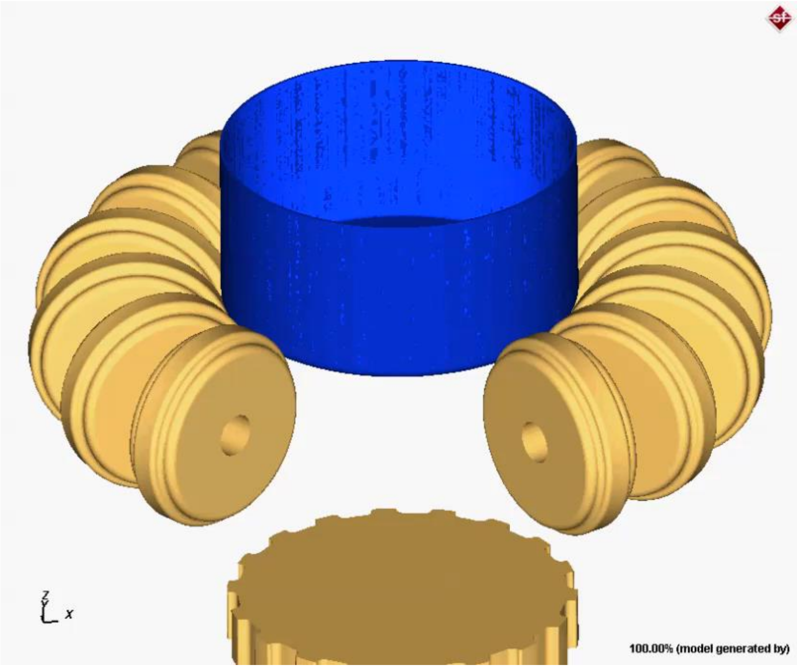
- Increased profitability by
  - Increased tool life
  - Higher output
  - Better machine usage
  - Improved product quality

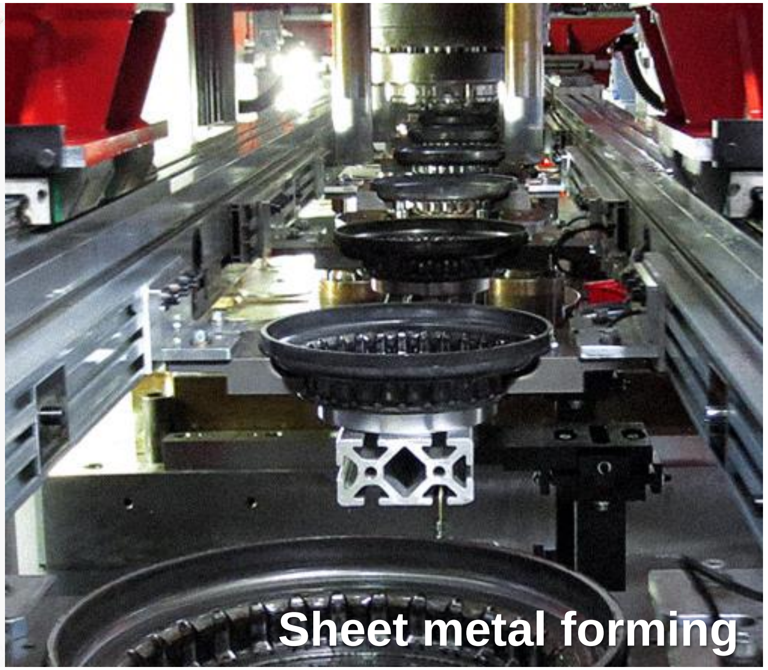




Sheet Metal Forming

- Proof of stage design
- Avoid geometrical defects like
  - Unwanted springback
  - Undesired thickness changes
- Avoid physical defects like cracks



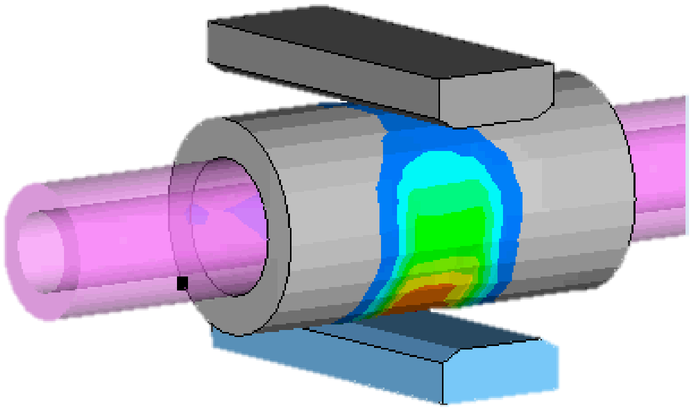


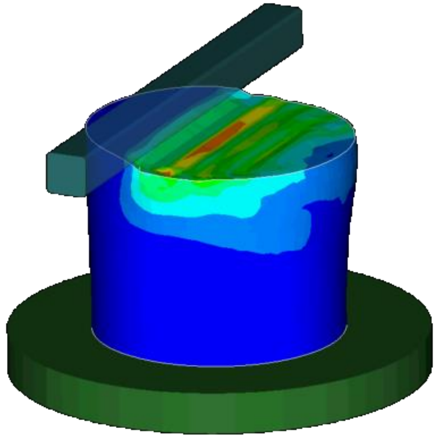
- Increased profitability by
  - Increased tool life
  - Higher output
  - Better machine usage
- Improved product quality

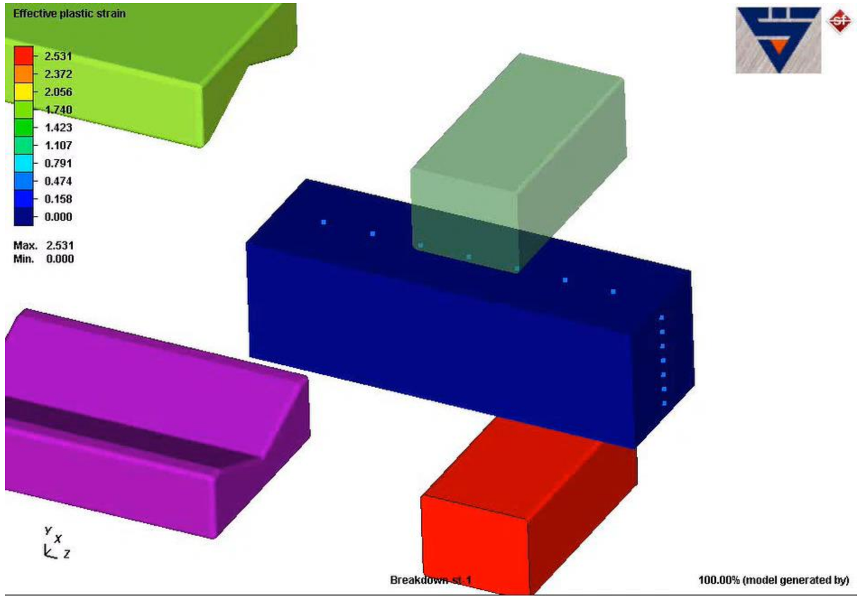
Shift physical testing to virtual testing!

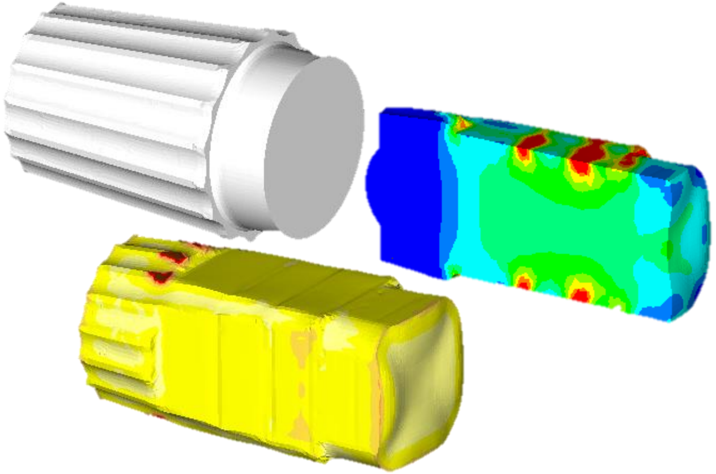
Incremental Forming

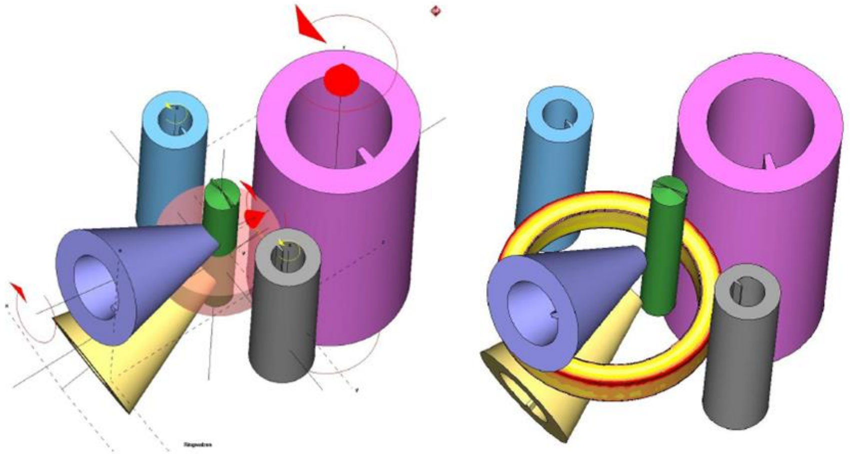
- Open die Forging
- Radial Forging
- Shell forging
- Rotational partial forging
- Ring Rolling



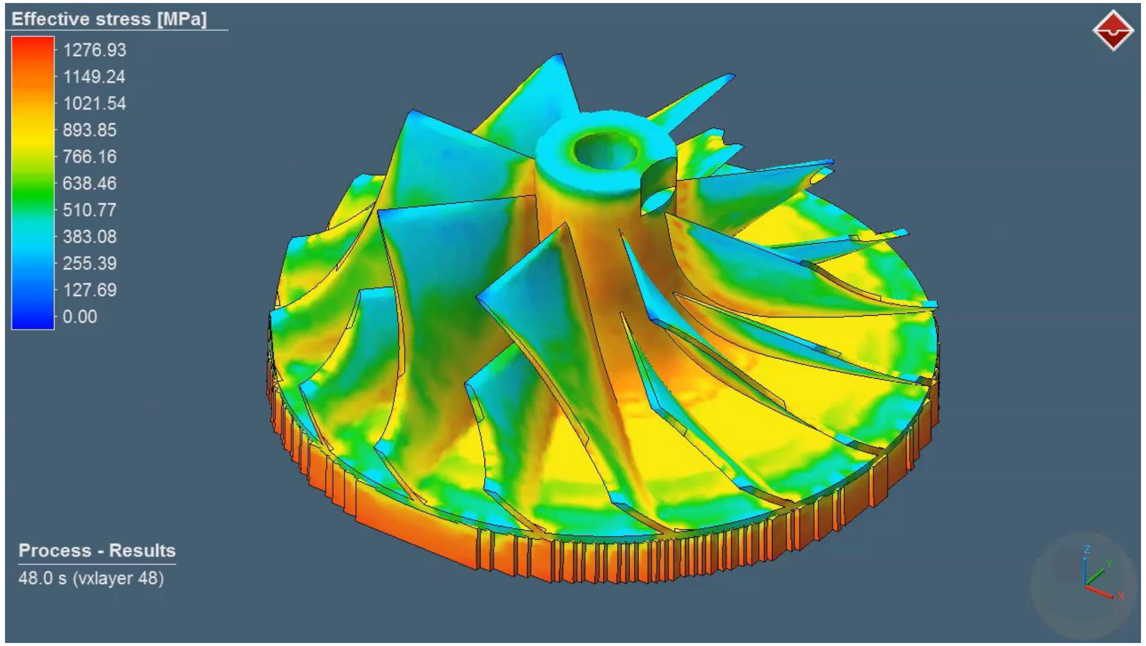








Metal Additive Manufacturing



Reduce physical testing !

- Obtain information about
  - Deformations
  - Residual stresses
- find suitable process parameters
- Reduce unwanted deformations
  - Try new support strategy
  - Change build orientation
  - Predistort the part

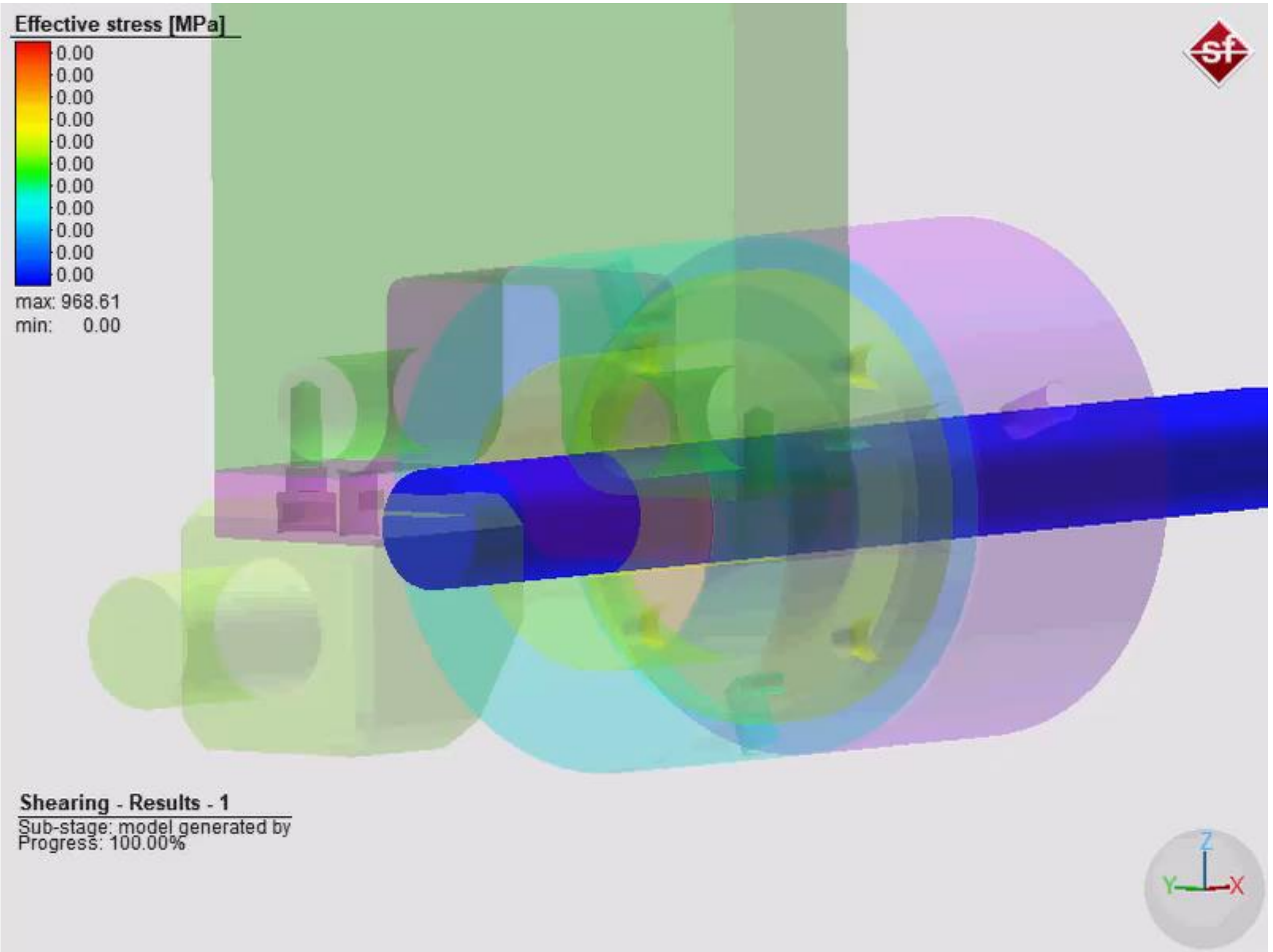
Forging Case Studies

Control arm
Gear

Control Arm

Shearing
Bending
Blocker
Finisher
Trimming
Quenching Tempering

Case Study : Hot Forging of a Control Arm

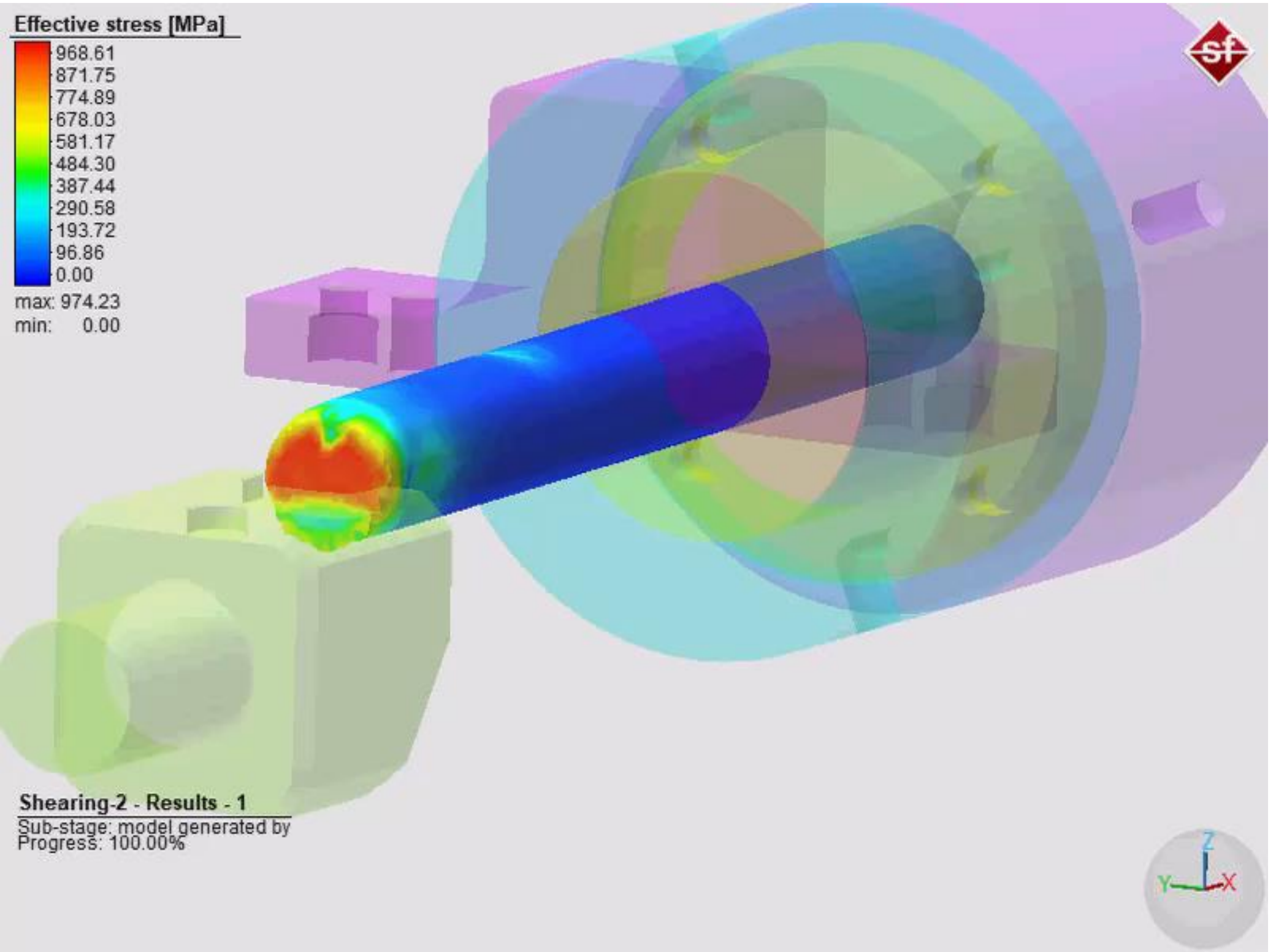


Solution time

Job information	
sfMarc Version	sfMarc 15.0 rev. 9241 based on MARC 2016 cl.460330
Job ends at increment	105
with exit number	3004
at loadcase	release_wp
forming loadcase ended based on	
stroke is reached	0.00 mm
defined stroke	0.00 mm
progress	100.00 %
wall time	1758.32 s
cpu time	40.5729 s

29 minutes and 18 seconds

Case Study : Hot Forging of a Control Arm

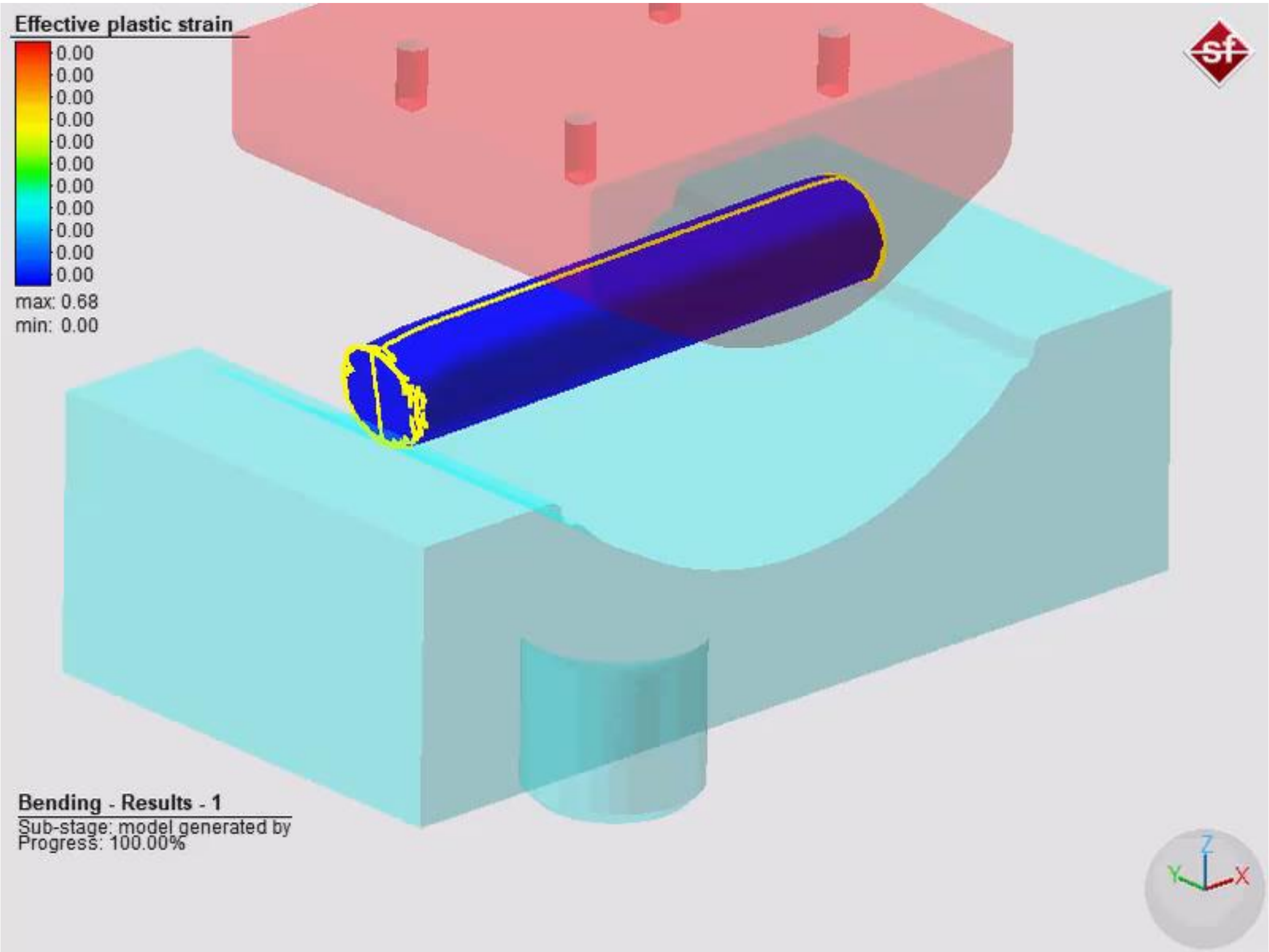


Solution time

Job information	
sfMarc Version	sfMarc 15.0 rev. 9241 based on MARC 2016 cl.460330
Job ends at increment	154
with exit number	3004
at loadcase	release_wp
forming loadcase ended based on	
stroke is reached	0.00 mm
defined stroke	0.00 mm
progress	100.00 %
wall time	2568.39 s
cpu time	31.6354 s

42 minutes and 47 seconds

Case Study : Hot Forging of a Control Arm



Solution time

Job information	
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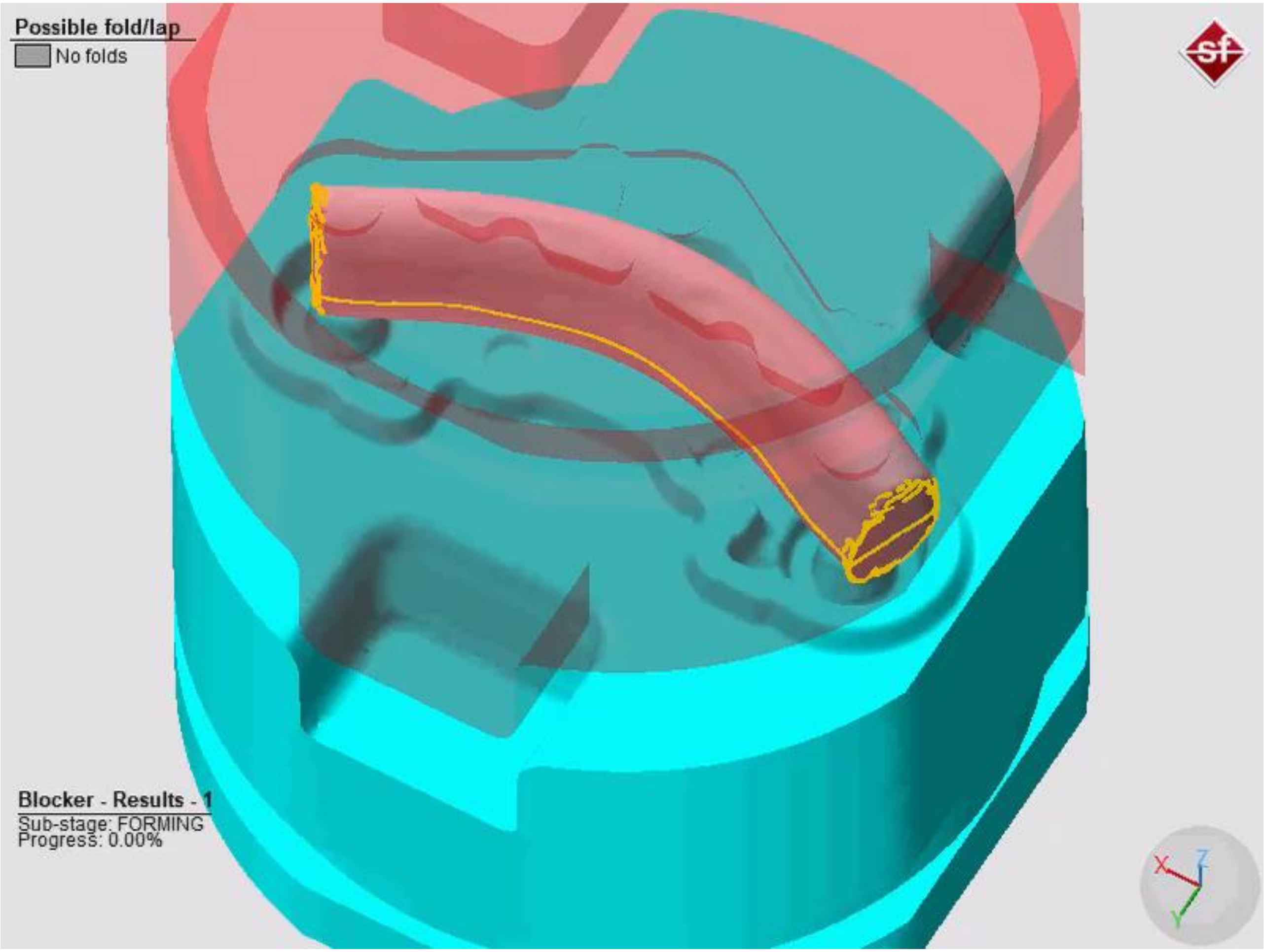
Job ends at increment	42
with exit number	3004
at loadcase	release_wp
forming loadcase ended based on	
stroke is reached	37.37 mm
defined stroke	37.37 mm
progress	100.00 %
wall time	264.797 s
cpu time	167.24 s

4 minutes and 25 seconds

Case Study : Hot Forging of a Control Arm

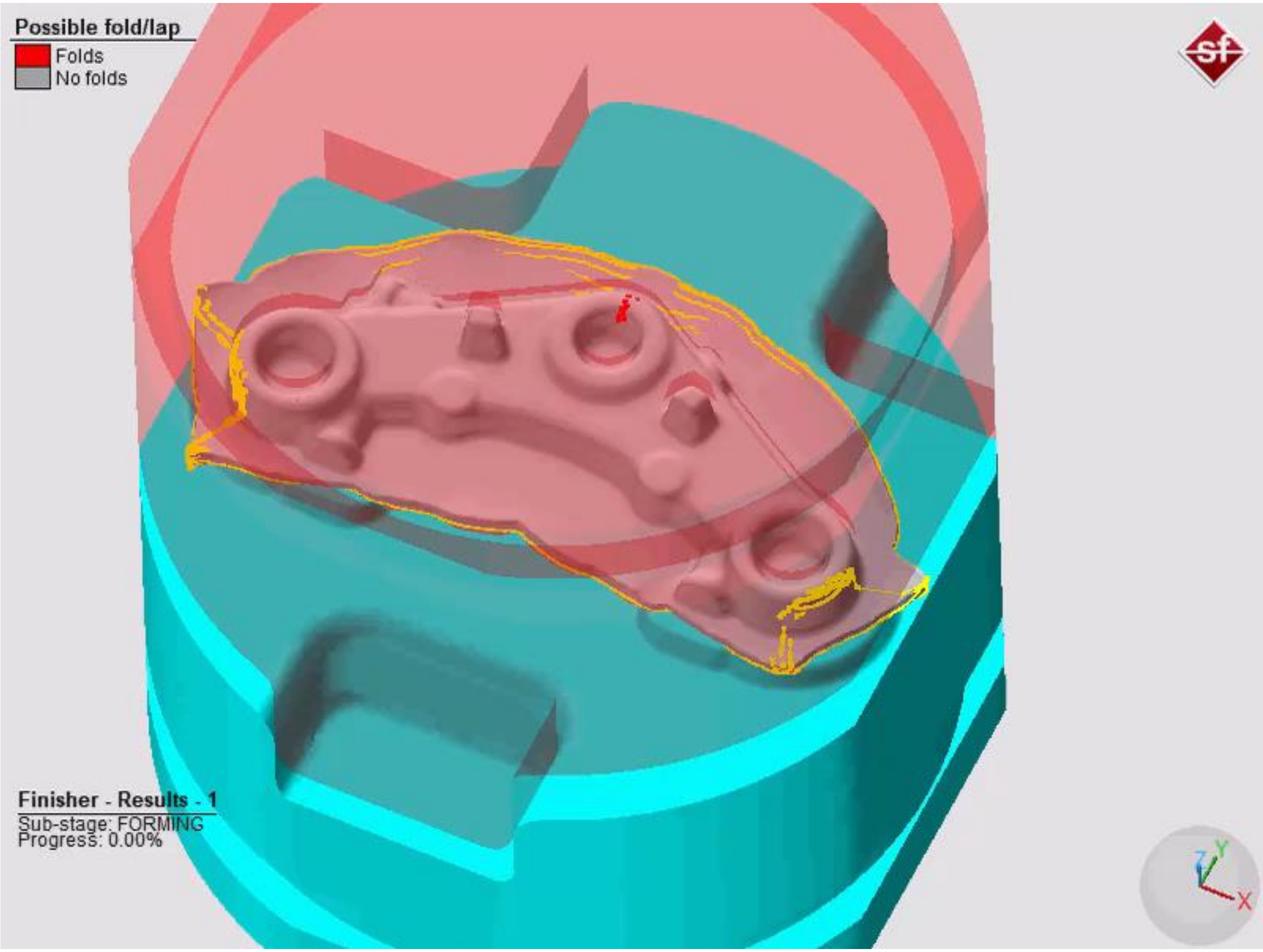


Solution time

Job information	
Dytran Build Date	Date
Job ends at increment	5635
with exit number	3004
progress	100.00 %
wall time	3664.0 s
cpu time	4435.31 s

61 minutes and 4 seconds

Case Study : Hot Forging of a Control Arm



Solution time

Job information	
Dytran Build Date	Date
Job ends at increment	1744
with exit number	3004
progress	100.00 %
wall time	1867.0 s
cpu time	2221.08 s

31 minutes and 7 seconds

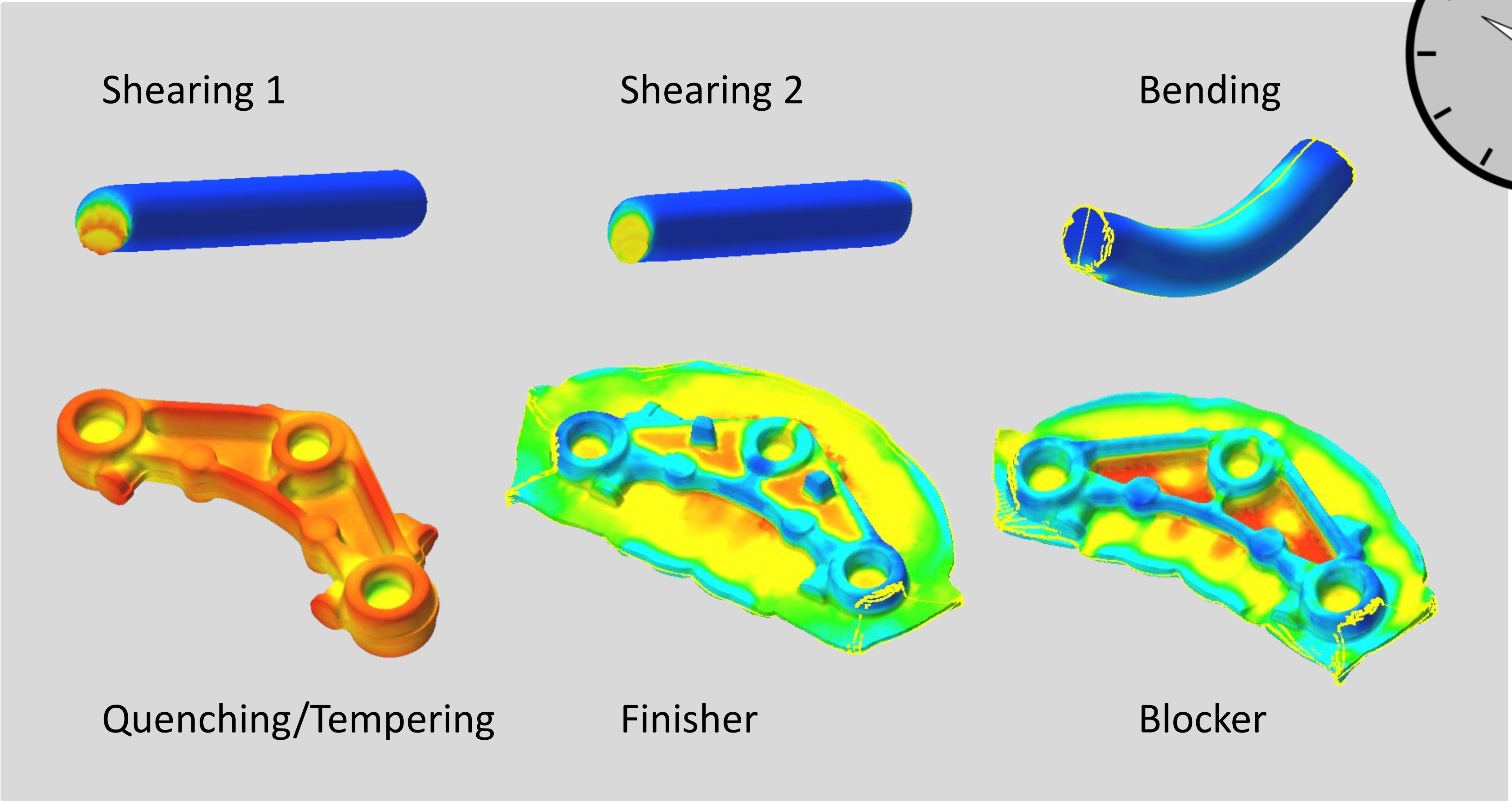
Case Study : Hot Forging of a Control Arm

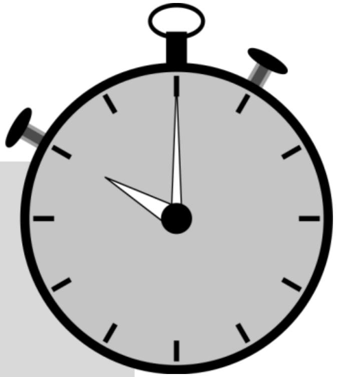
Solution time

Job information	
sfMarc Version	sfMarc 15 beta rev. 8747 based on MARC 2016 cl.460330
Job ends at increment	119
with exit number	3004
at loadcase	cooling
forming loadcase ended based on	
terminated on time	0.00 sec
end time defined	0.00 sec
progress	100.00 %
wall time	1734.21 s
cpu time	1621.83 s

28 minutes and 53 seconds

Case Study : Hot Forging of a Control Arm





3 hours and 17 minutes

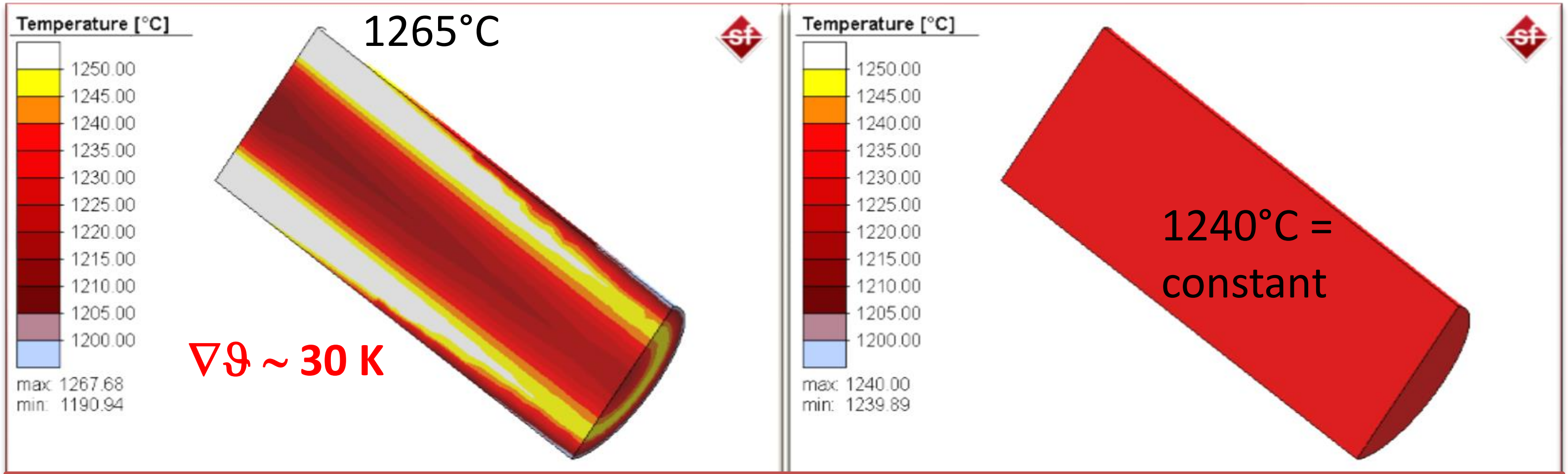
On Dell XPS
4-Core System

Gear

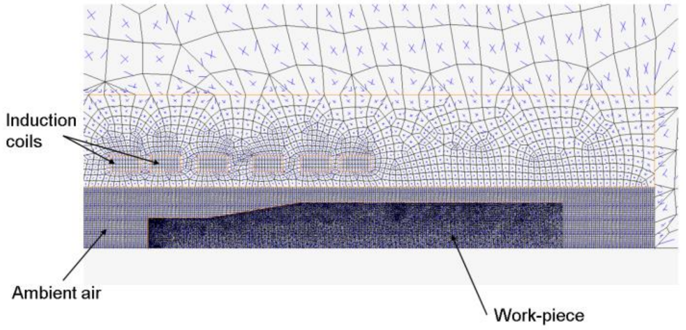
Heating
Forging
Heat Treatment
Welding

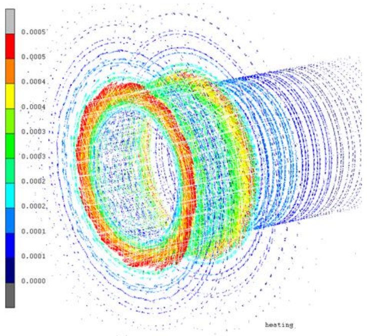
Case Study : Process Chain

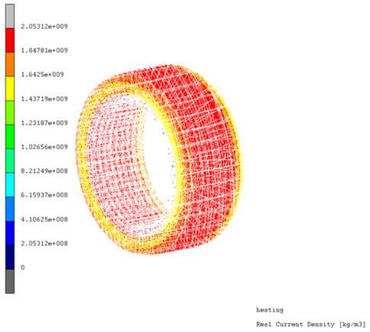
Induction Heating



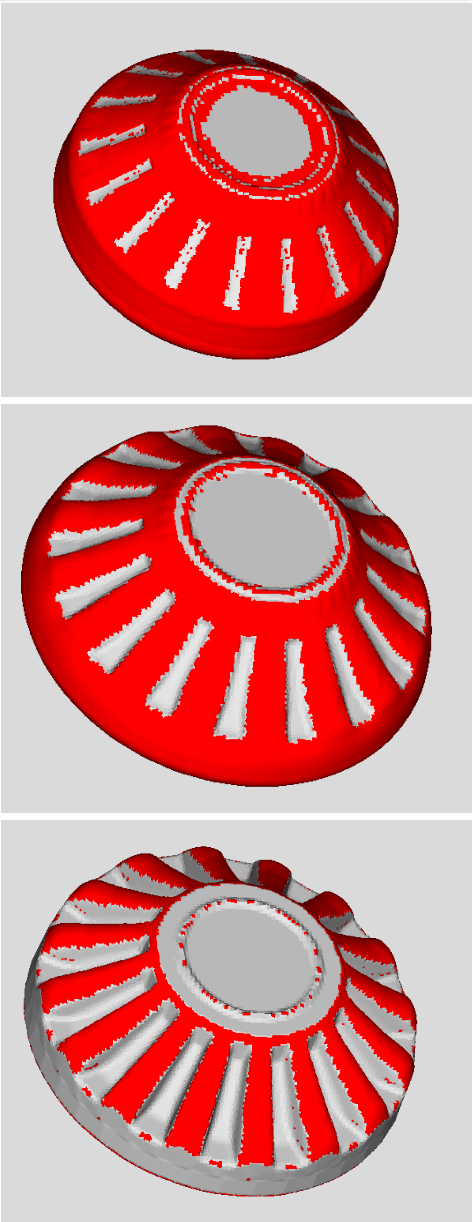
Simulation of induction heating (left) vs. constant temperature field (right)







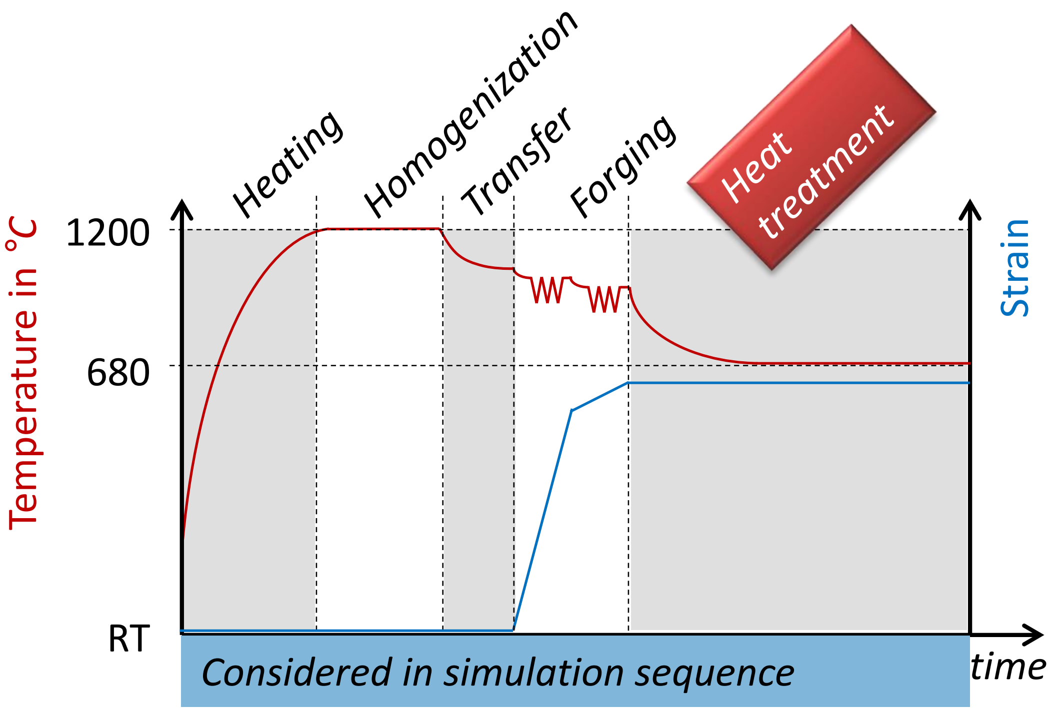
Forging



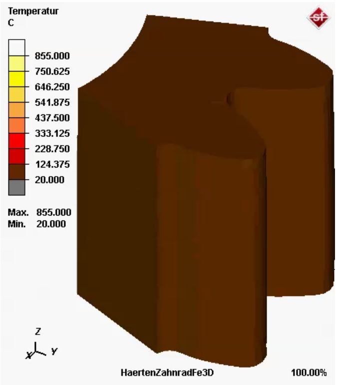
Case Study : Process Chain

- **Classical quenching & tempering**
- Carburizing (case hardening)

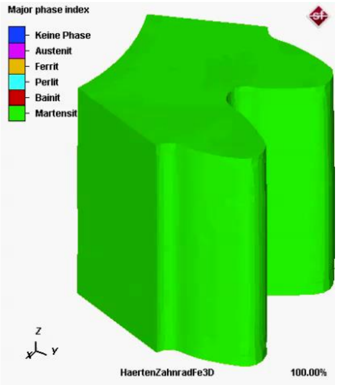
Heat treatment: changing properties/strengths → influences effective stresses / Hertz pressure → hence influences pitting



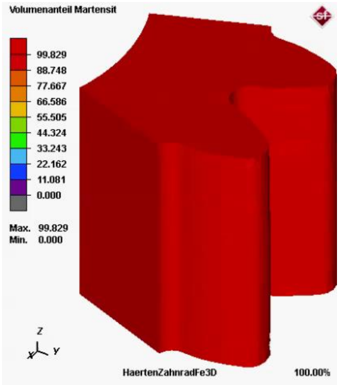
Temperature [°C]



Dominating phase

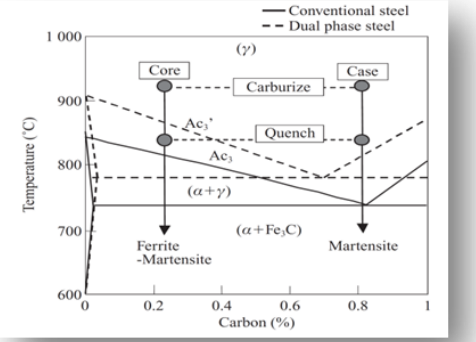


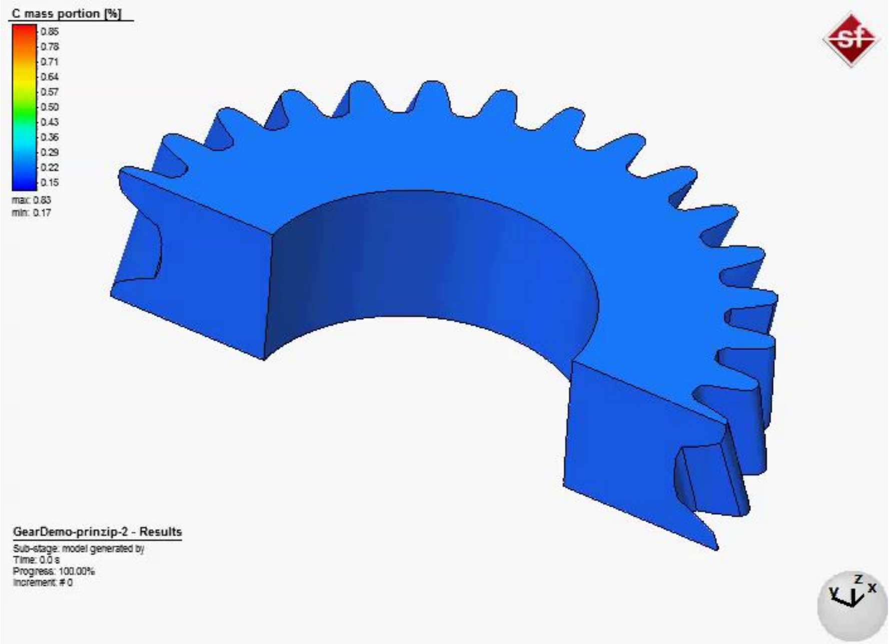
Vol. fraction Martensite [%]

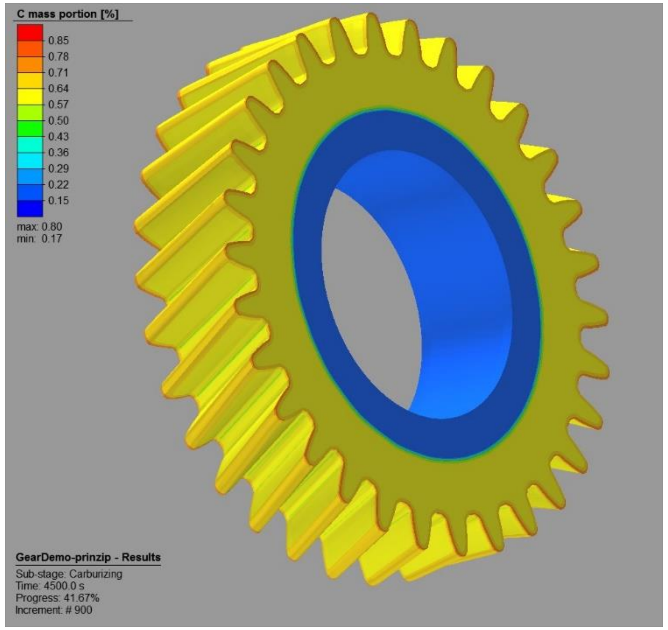


Case Study : Process Chain

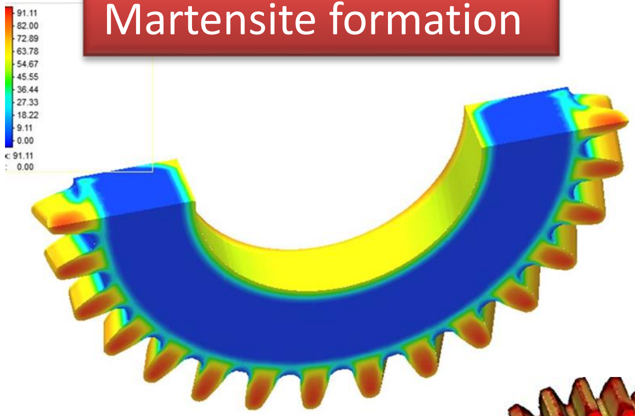
- Classical quenching & tempering
- **<u>Carburizing (case hardening)</u>**

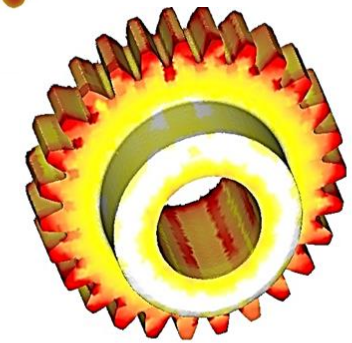






Martensite formation

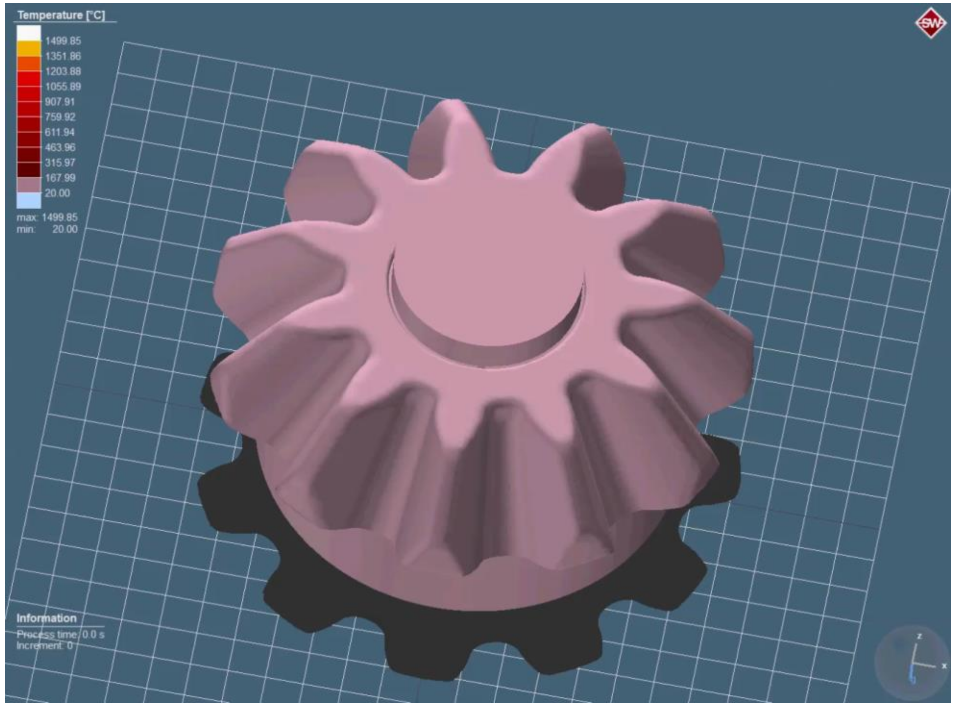


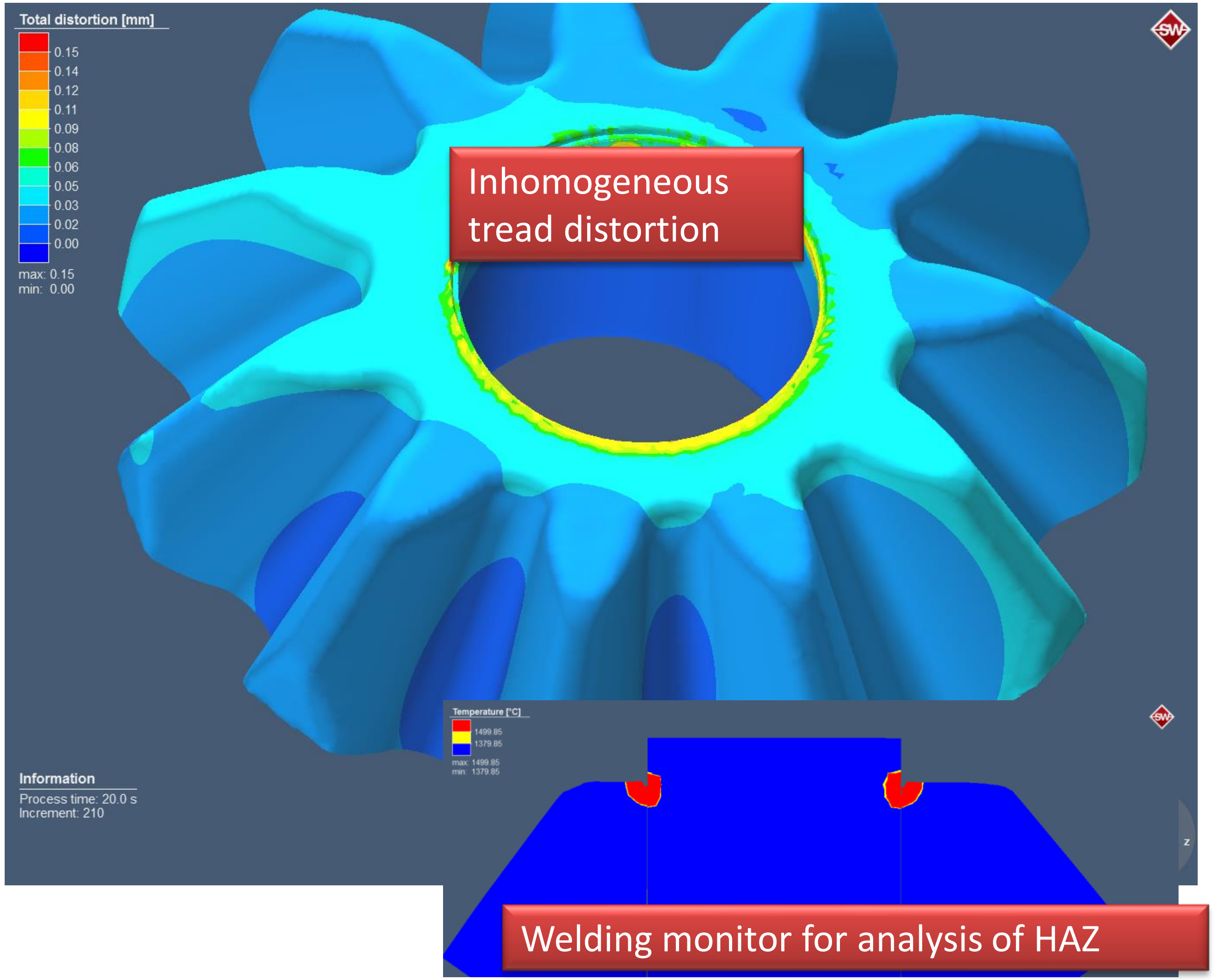


Heat treatment: changing properties/strengths → influences effective stresses / Hertz pressure → hence influences pitting

Case Study : Process Chain

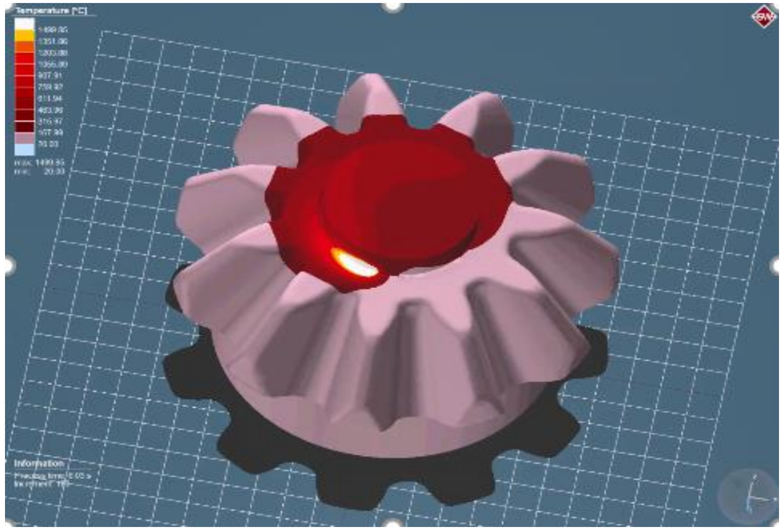
- Laser welding
- Beam welding



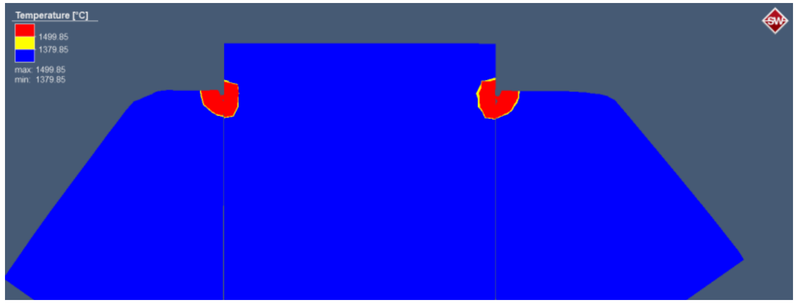


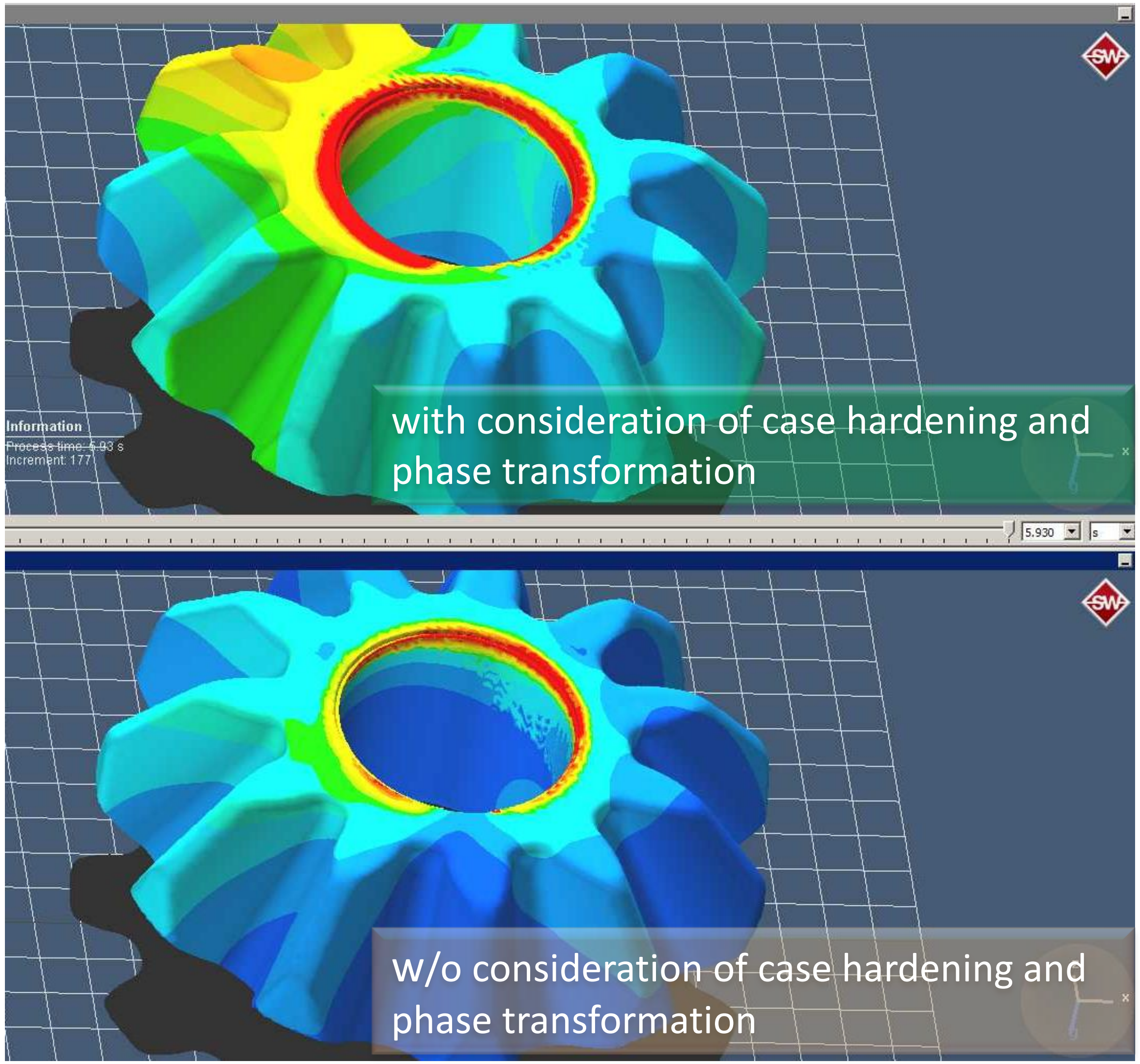
welding: causes local changes of properties/strengths & distortions → influences effective stresses / Hertz pressure → hence influences pitting

Case Study : Process Chain

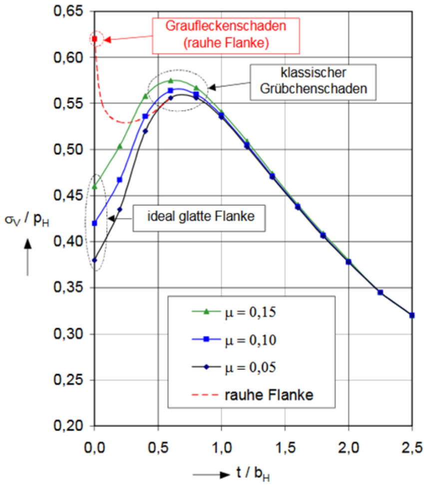


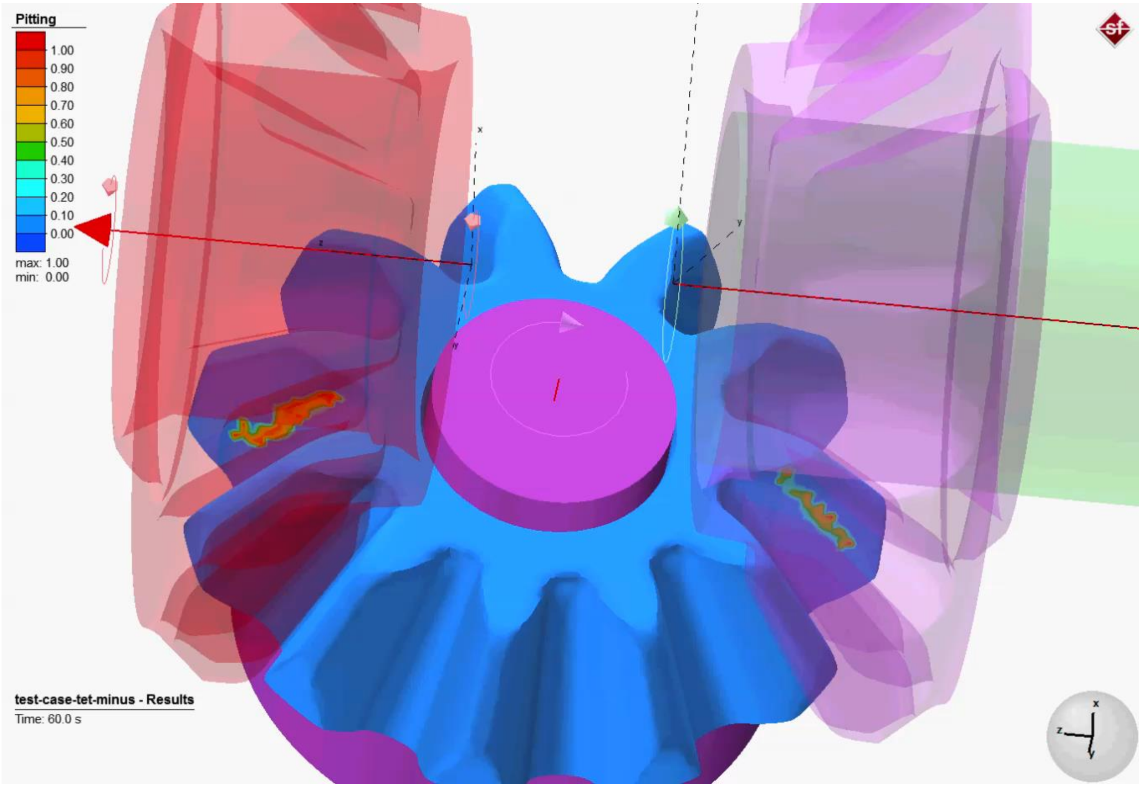
Welding simulation of a formed gear



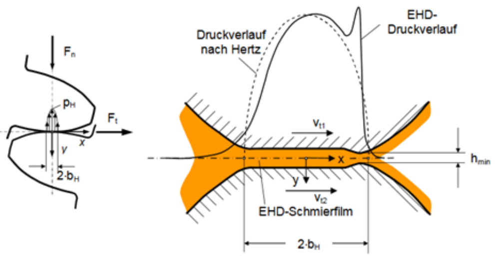


Case Study : Process Chain





Contact & pitting analysis



3D-Printing Case Study

Light weighting : Hood Hinge

Case Study

Additively manufactured lightweight engine hood hinge

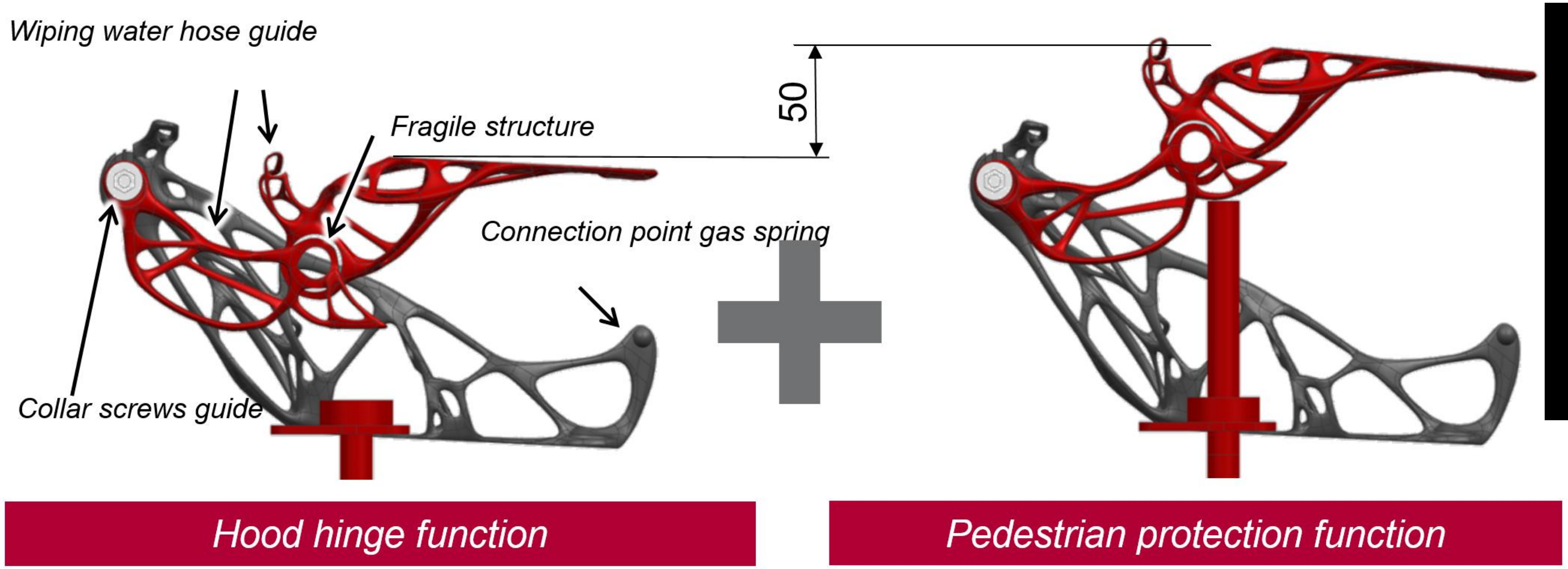
LightHinge+

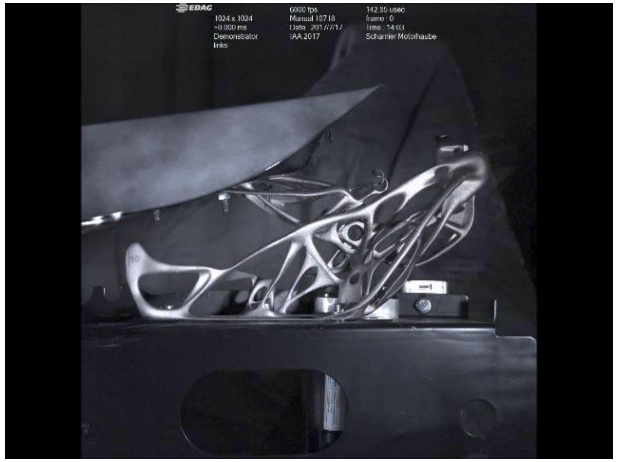
GOLD AWARD CO_2

LightHinge+ - The Concept

Our goal for the small series and sports car segment:

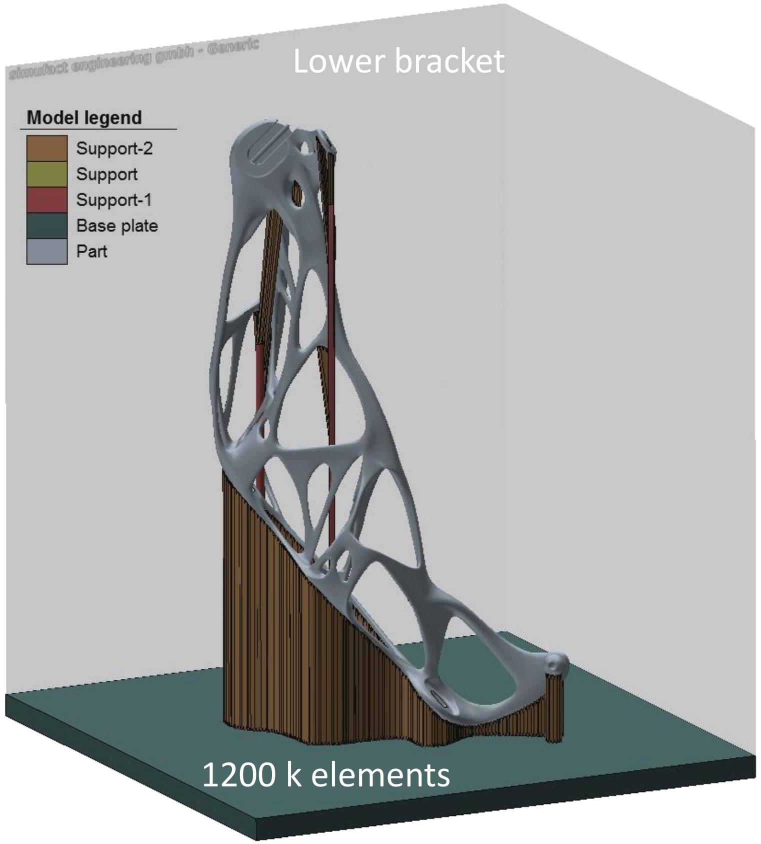
- Ultra lightweight
- Maximum component and function integration
- Integrated pedestrian protection function
- Tool-less and update-capable production

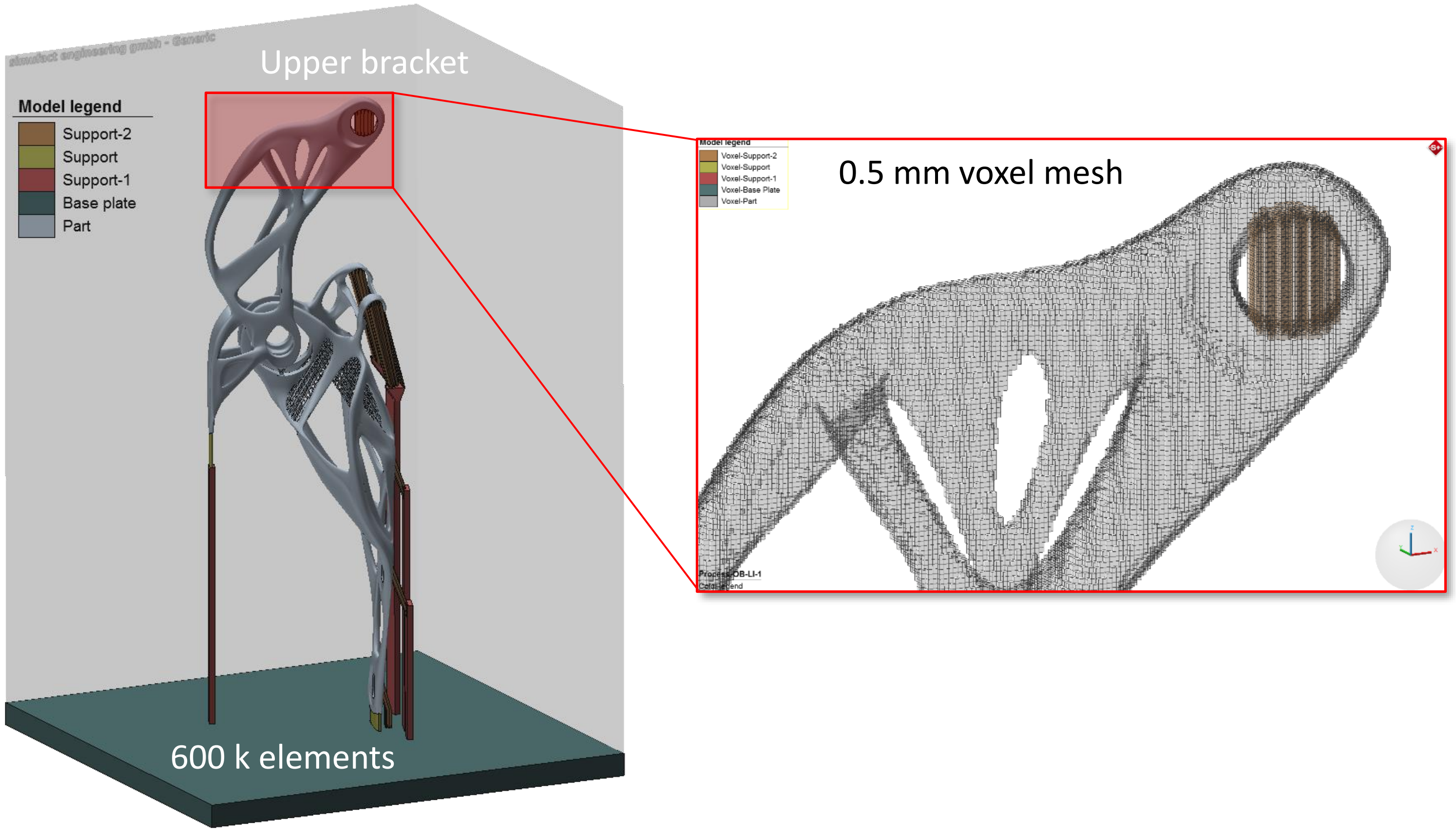




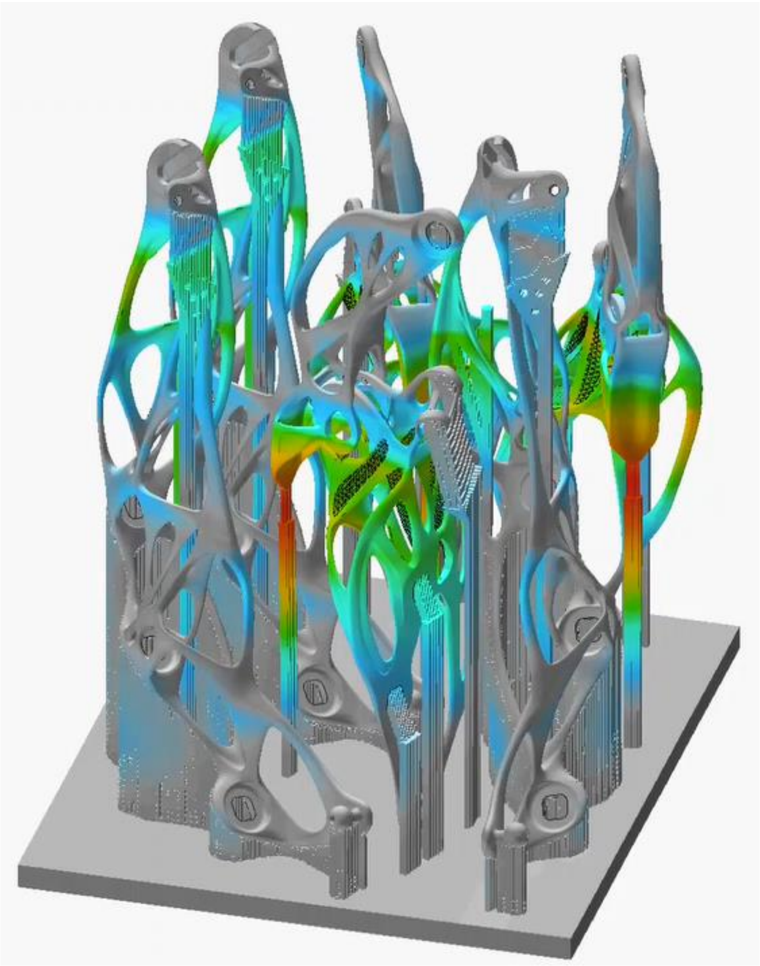
Model setup for AM simulation

- Import part geometry
- Import support structure geometries
- Select material from database – 316L steel
- Define process chain to be simulated (build part, cut from plate, remove supports)
- Mesh geometries with voxels





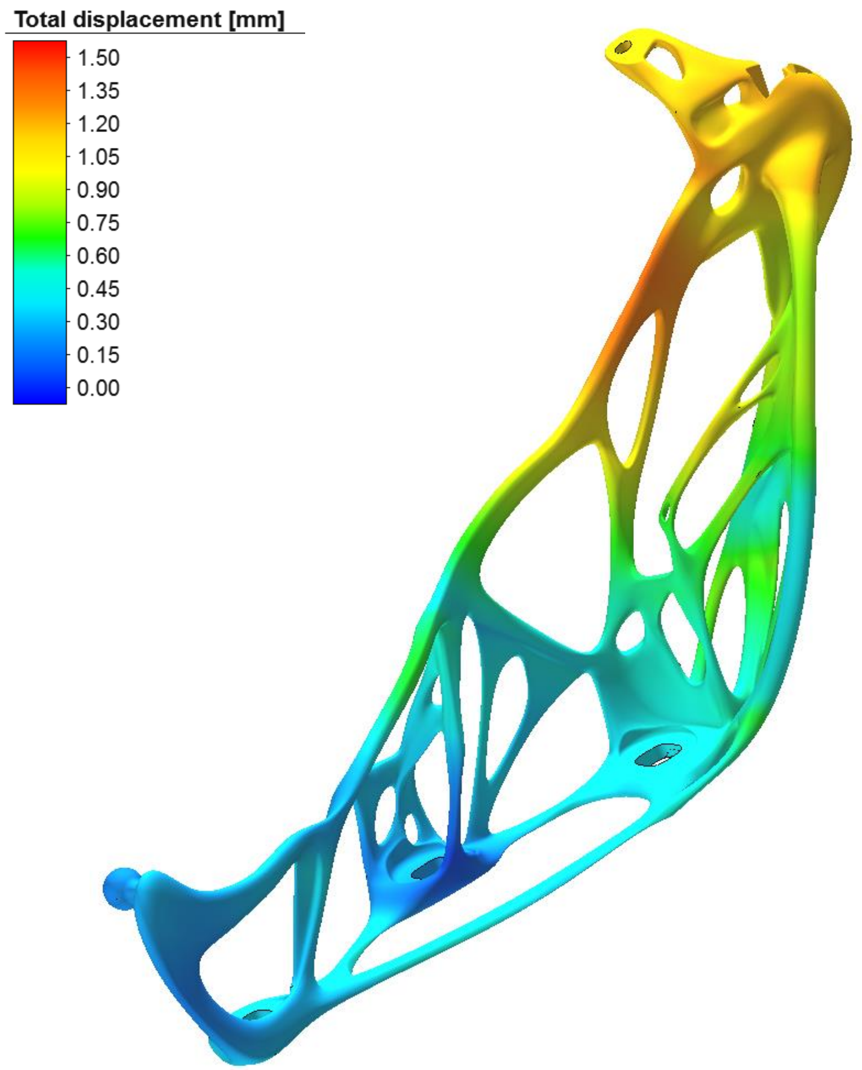
AM simulation of real-life build space

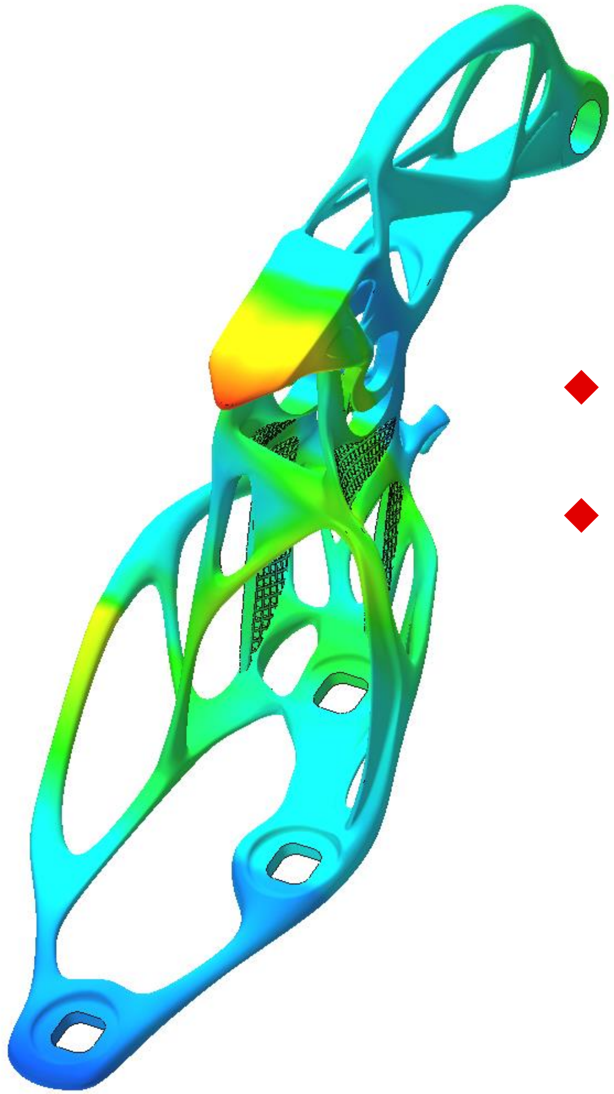


- Actually six parts are manufactured simultaneously
  - 3 lower brackets
  - 3 upper brackets
- Simulation of
  - Building the parts
  - Cutting from plate
  - Removing support structures
- Total displacement shown
- For demonstration only!
- Single part analysis to be preferred

AM simulation results

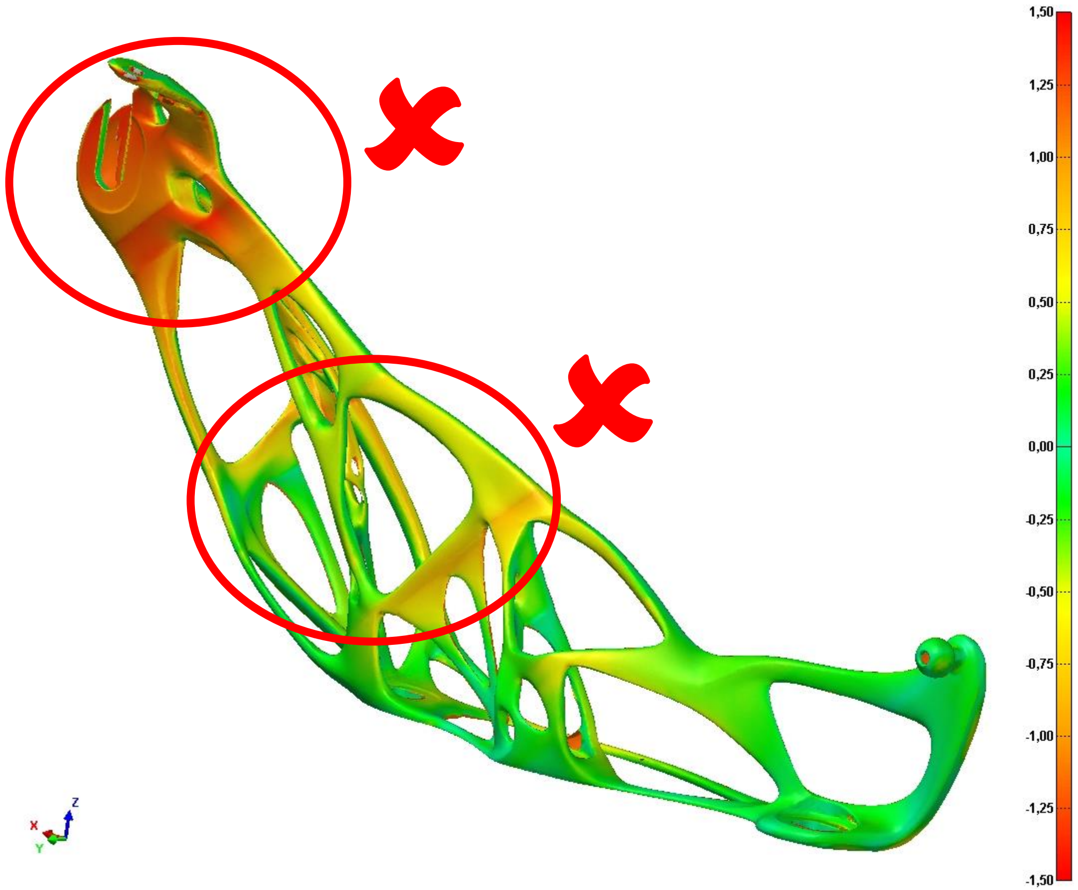
simufact additive



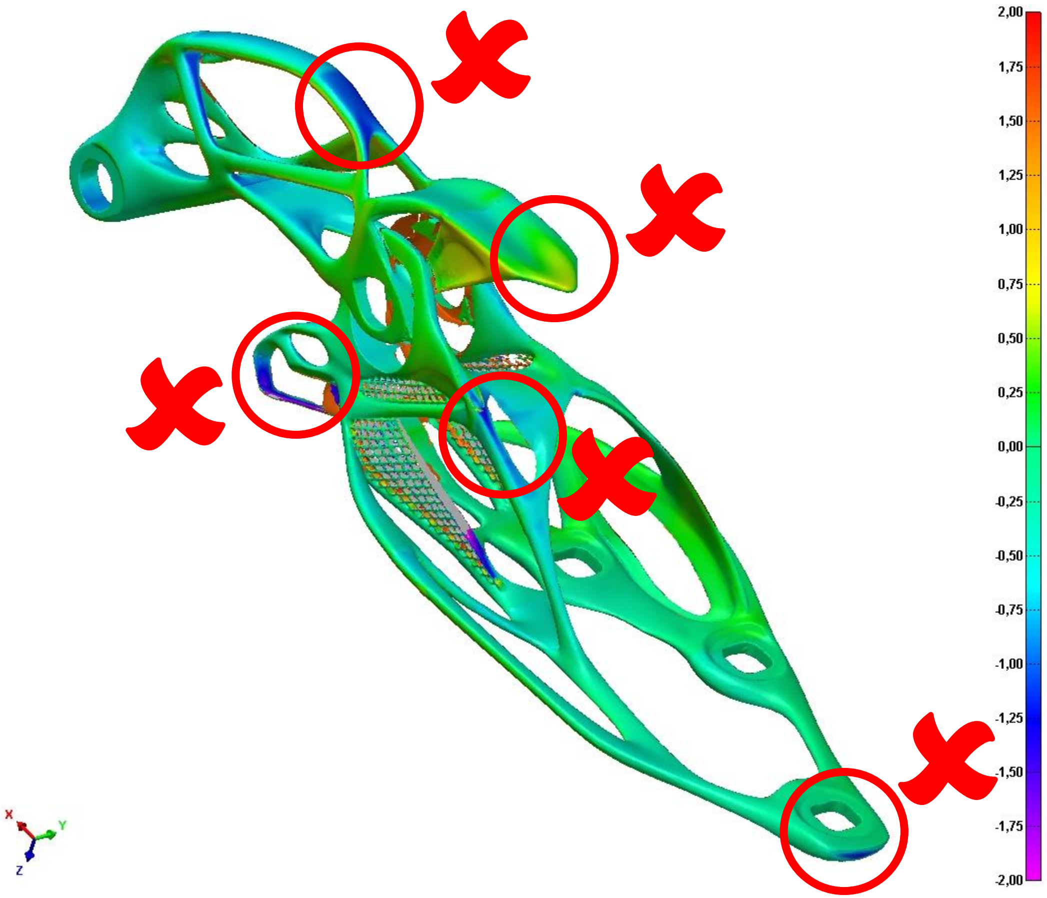


- **Total displacement** shown
- Other results available:
  - Residual stresses
    - ➔ **Risk of tearing**
    - ➔ **Support separation**
  - Layer-Z displacement
    - ➔ **Risk of wiper collision**

Distortion of manufactured part vs. CAD



Lower Bracket



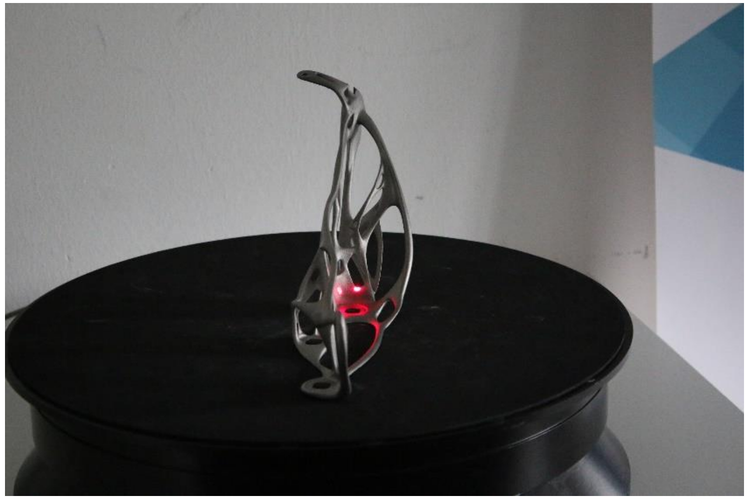
Upper bracket

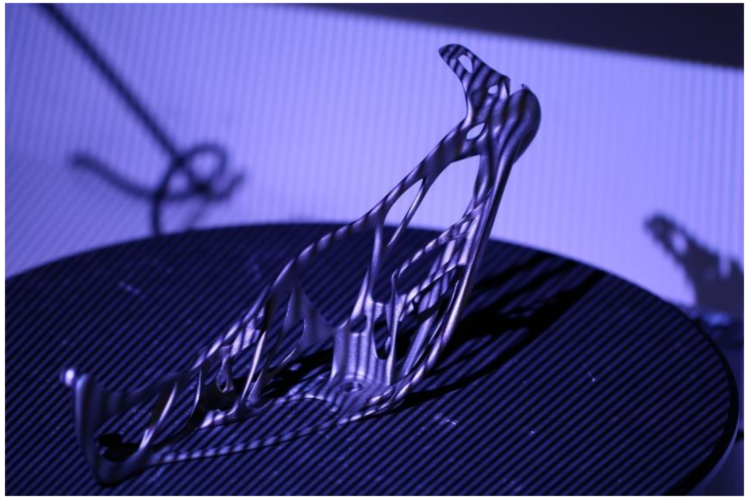
Validation by optical measurement

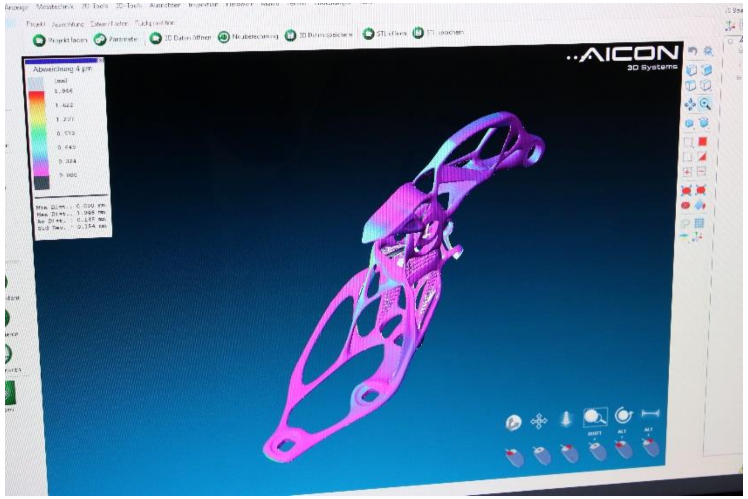
With kind support from

AICON 3D Systems

HEXAGON MANUFACTURING INTELLIGENCE







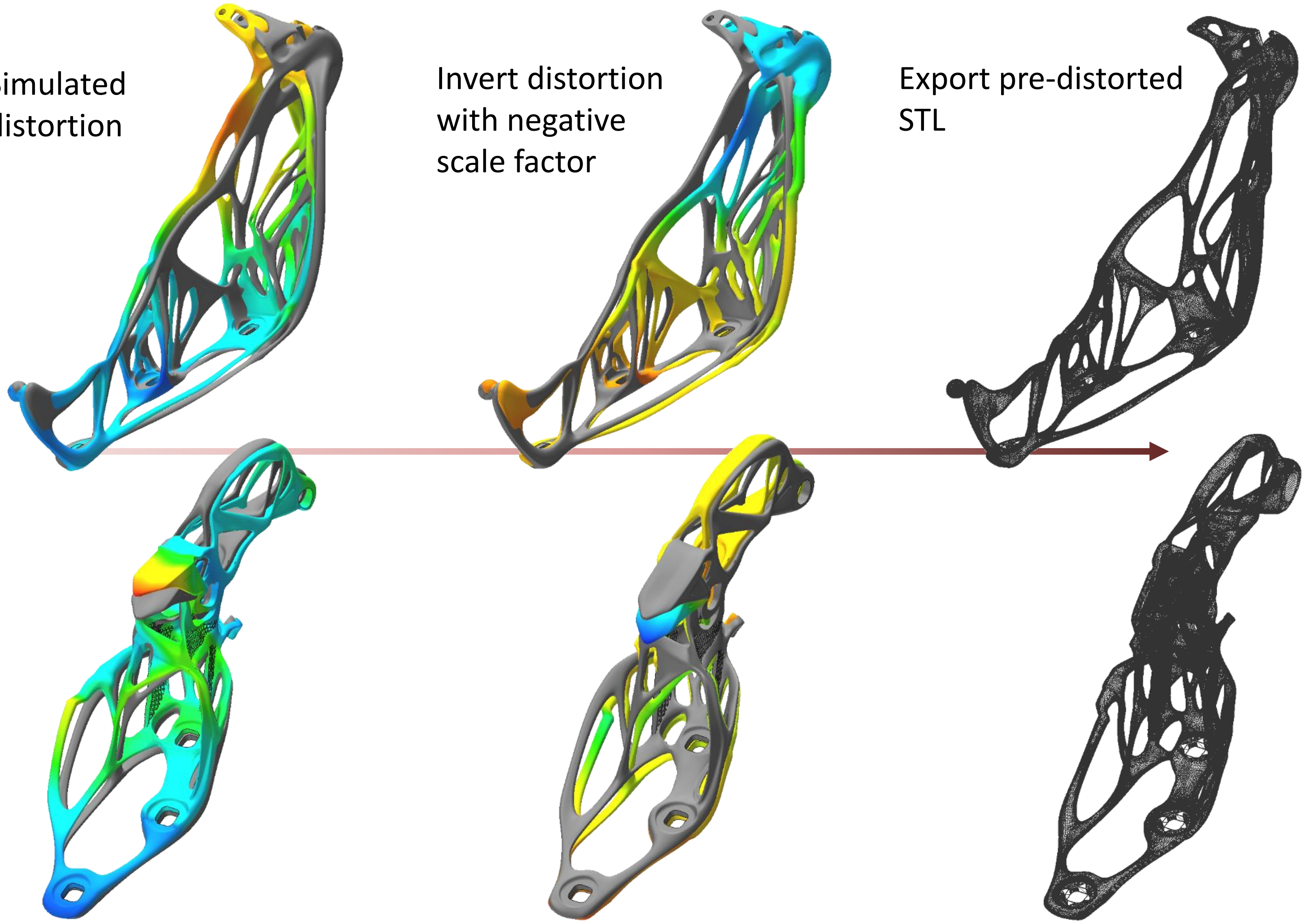
Pre-deformed shape for distortion compensation

simufact additive

Simulated distortion

Invert distortion with negative scale factor

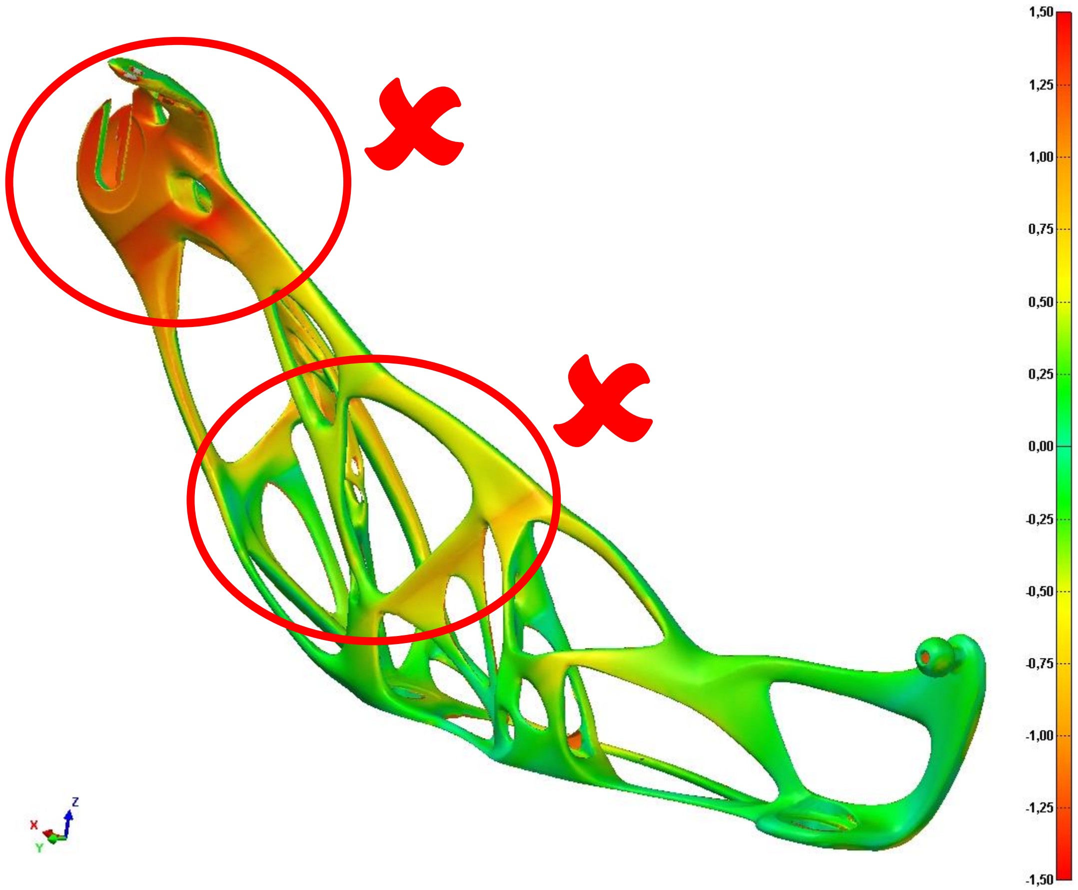
Export pre-distorted STL



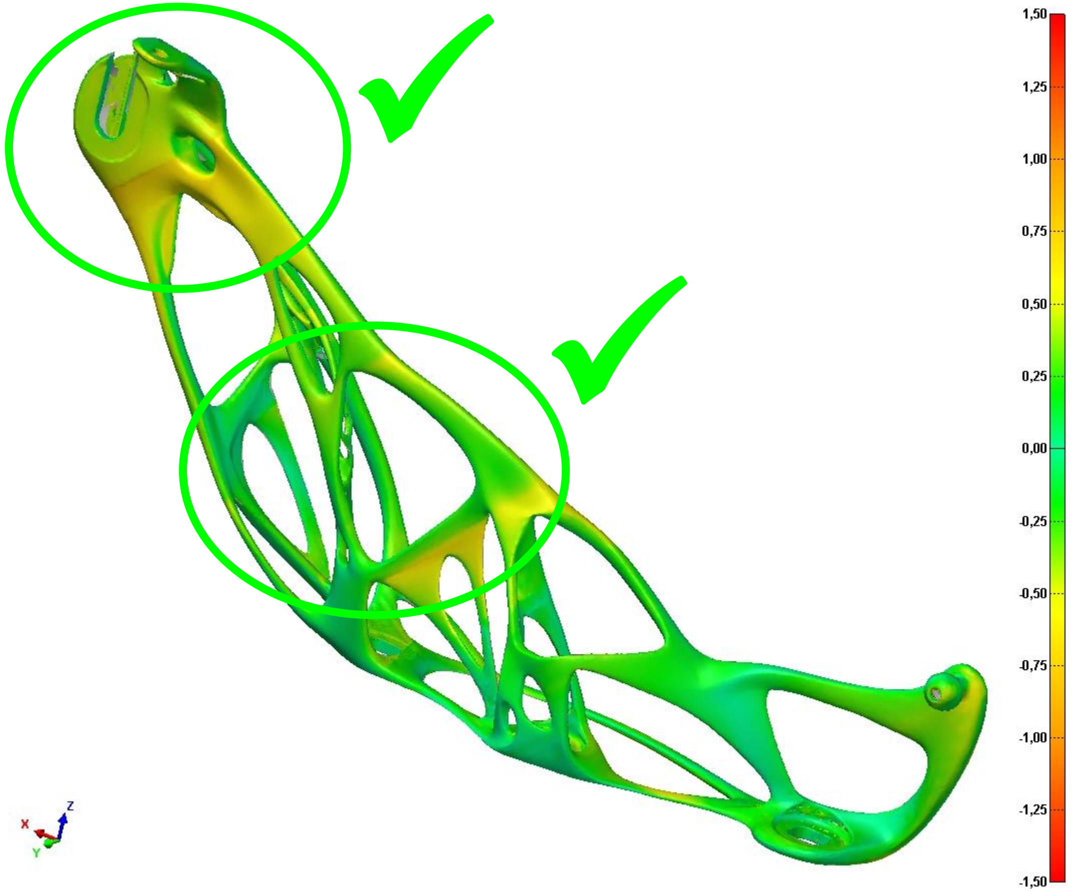
- Simulated distortion is inverted
- Inverted distortion is mapped on surface STL
- Pre-distorted STL is exported
- Exported STL was used for optimized AM of distortion compensated parts

NB: shown distortions are overscaled by a factor of 10 for better visualization

LightHinge+ lower bracket

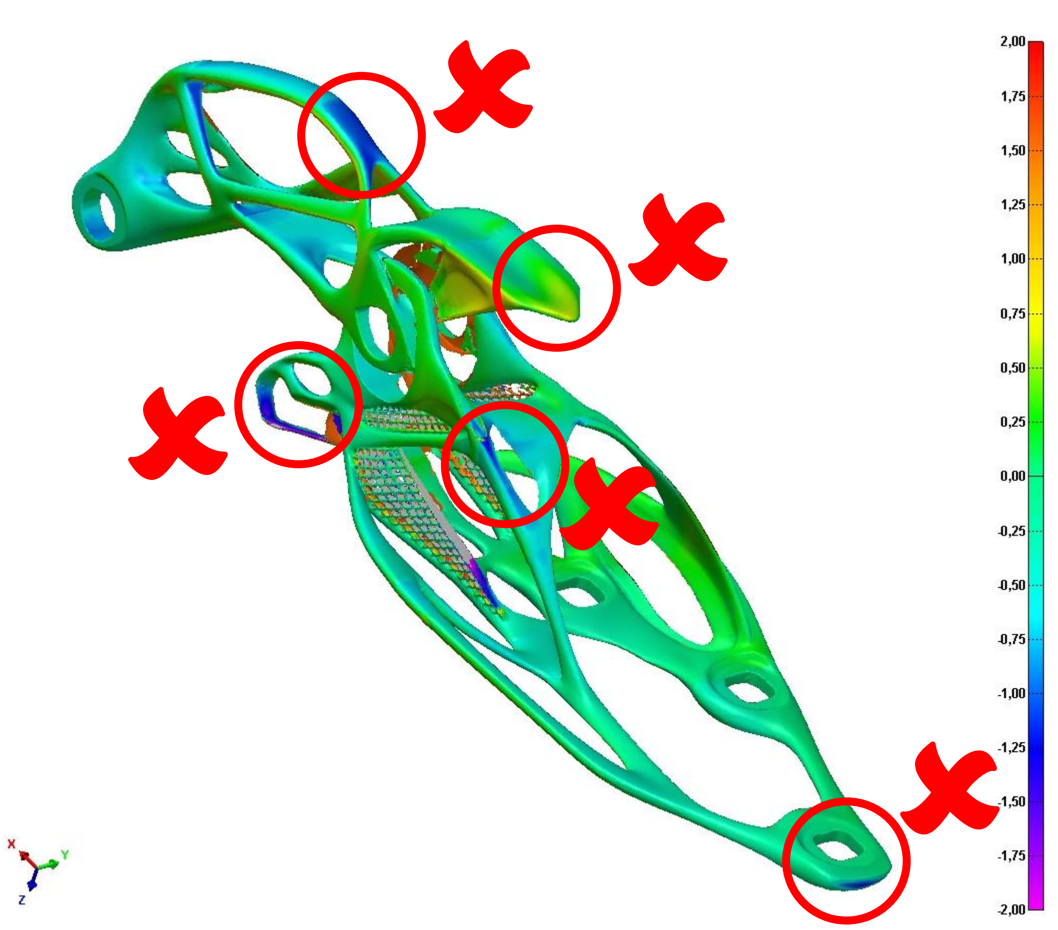


Original distortion of manufactured part vs. CAD

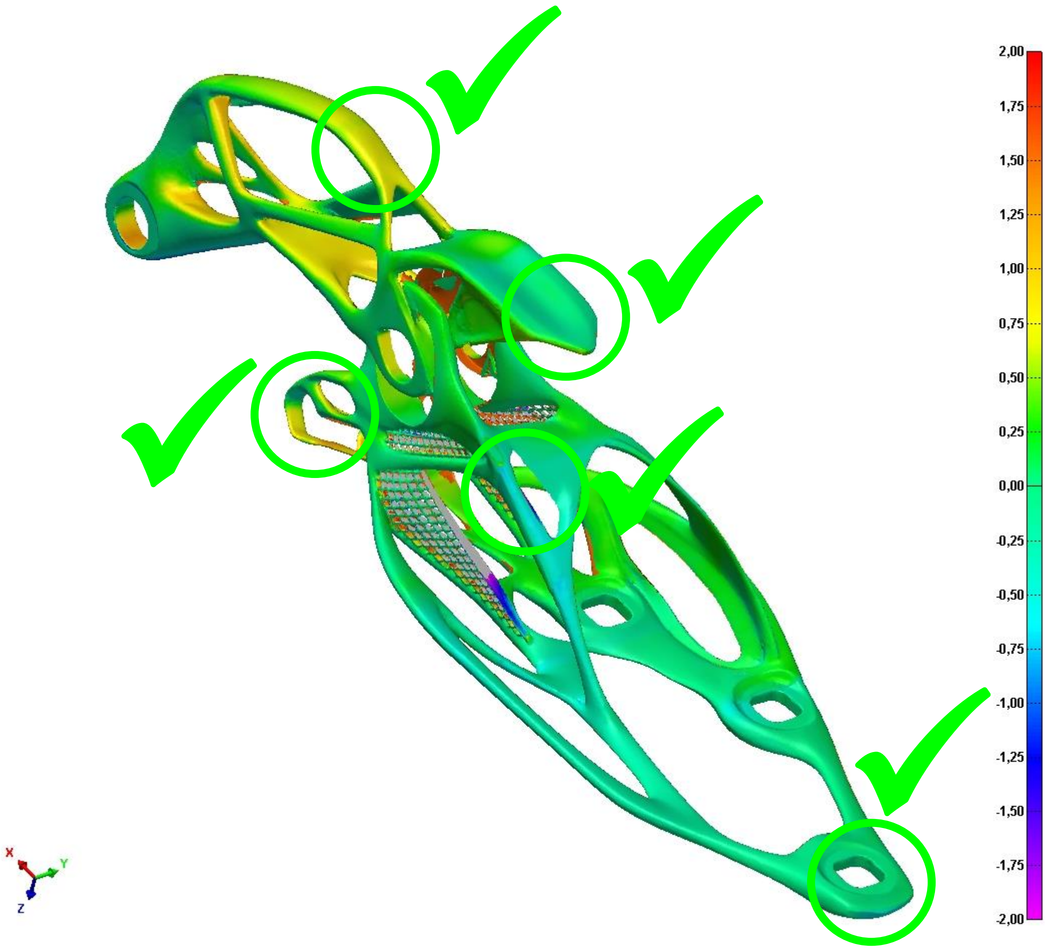


Distortion compensated based on simulation results

LightHinge+ upper bracket



Original distortion of manufactured part vs. CAD



Distortion compensated based on simulation results

Conclusions

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◆ Maximum distortion was cut by half from about 1.5 mm to 0.75 mm.

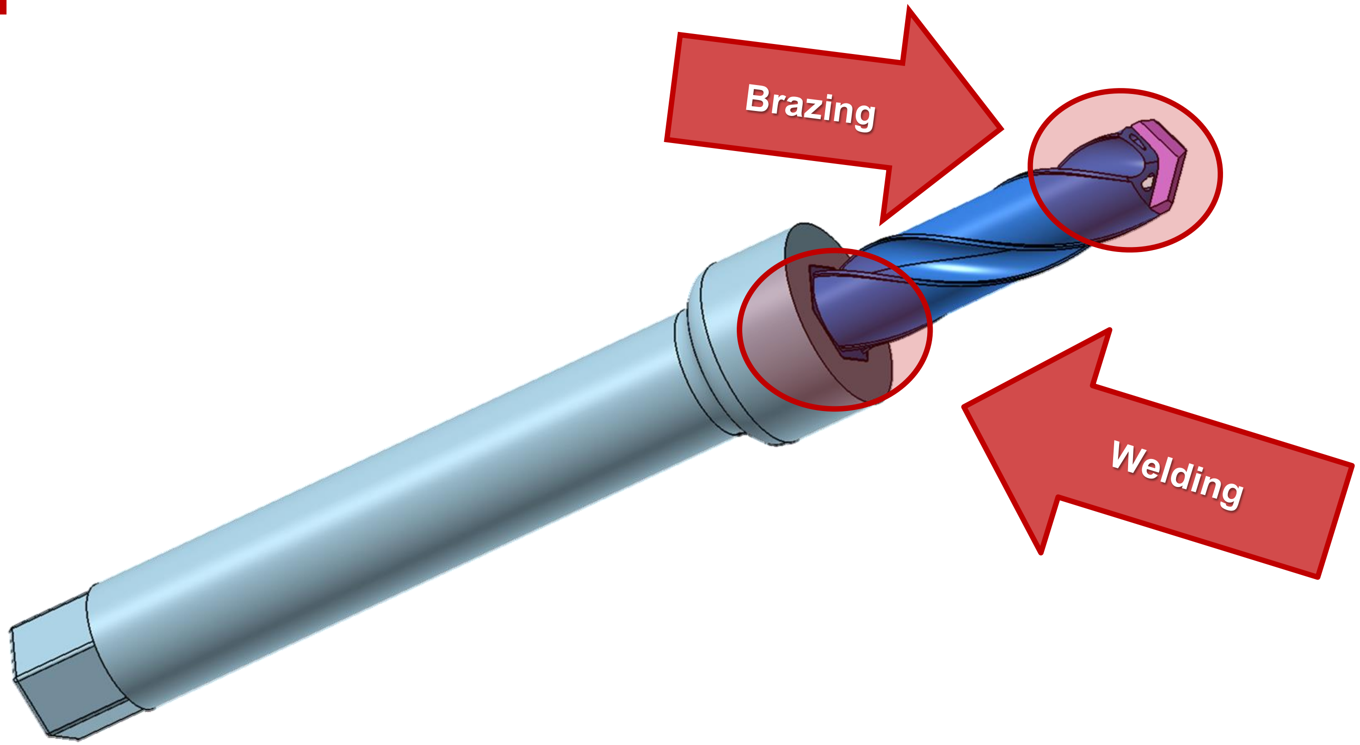
➔ **AM part was within the given tolerances after the first build job!**

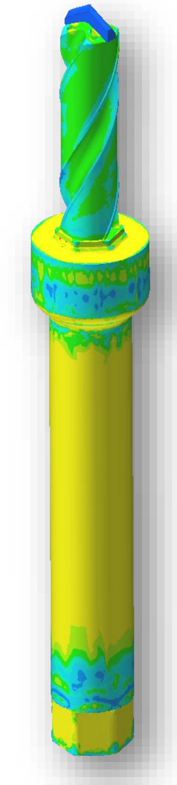
◆ No necessity for building costly and time consuming trial parts.

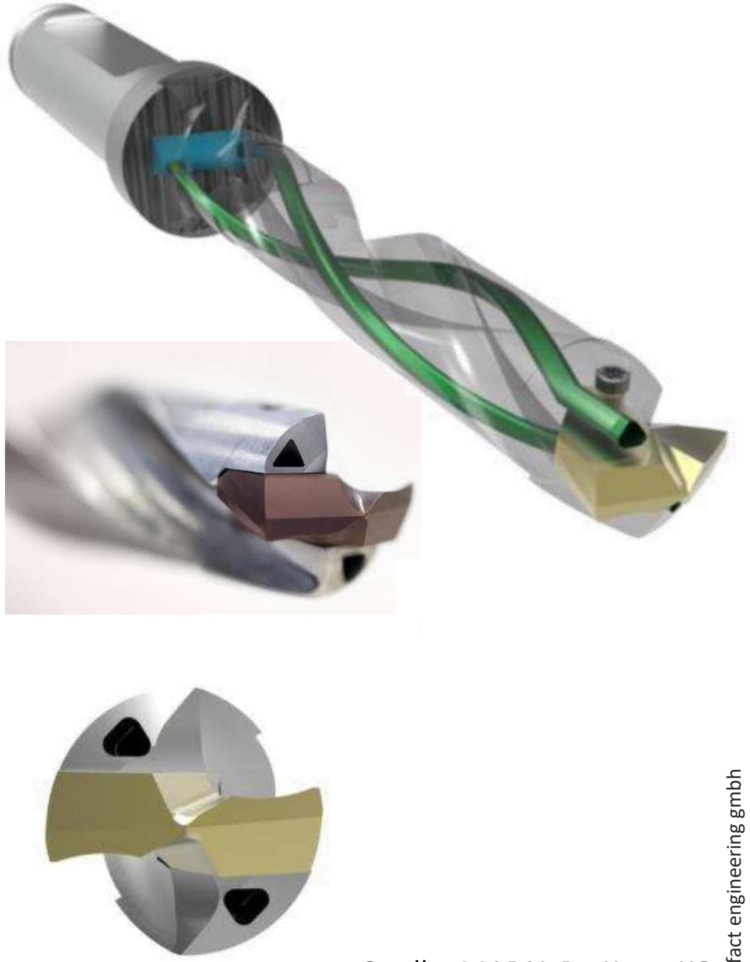
◆ No necessity for expensive compensation of distortion based on optical measurements.

➔ **Manufacturing time and costs are reduced dramatically!**

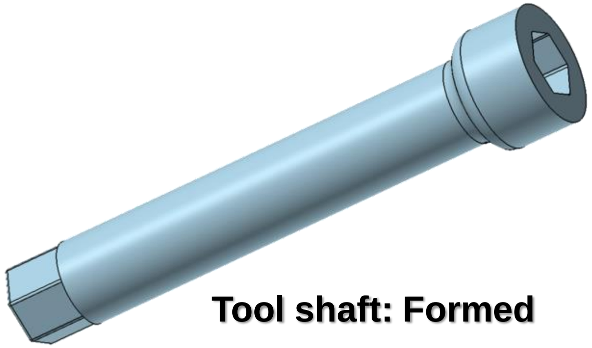
Trend complex hybrid parts



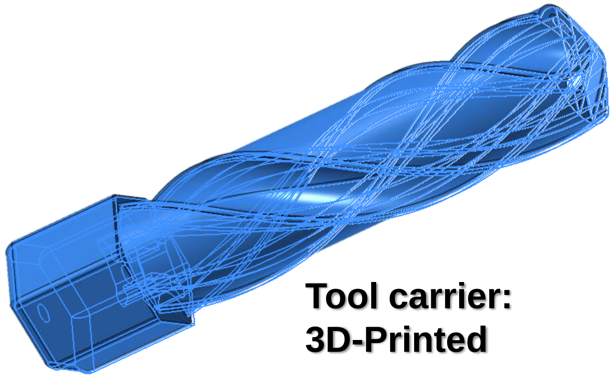




Quelle: MAPAL Dr. Kress KG



Tool shaft: Formed



Tool carrier:
3D-Printed

Cutting insert: Sintered

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Time for Questions

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