HxGN
Virtual Manufacturing

Forecasting Joint Quality :
Simulation for Metal Joining

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Design and Engineering business unit
Manufacturing Intelligence Division
Hexagon

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Agenda

1. Introduction to Hexagon Solutions
2. Manufacturing process simulation offerings from Hexagon

   Sheet metal Forming and Welding
   Forging: Bulk Metal Forming
   Additive Manufacturing
3. Manufacturing Simulation for Metal Joining Applications
4. Process Chain Simulation : Forming...Welding.. Structural… Fatigue
5. Questions

Hexagon Solutions

Smart Manufacturing is in our DNA

Hexagon MI's heritage and expertise is in manufacturing data, with digital touchpoints that converge the physical and digital worlds throughout the entire process: from concept to customer.

49,000
Leading manufacturers using our technologies

Over 500,000
installed software licenses

Satisfied customers:
95% renewal rate, 4.5/5.0

95%

90%

85%

Virtual

Physical

Trusted **CAE Simulation**

Design & Engineering

#1 in **CT Software**
(Frost & Sullivan)

Production

#1 in **CAM**
(CIMData)

Quality

#1 in **Metrology Scanners**

Service

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Hexagon’s Product Portfolio

Digital Quality Management System

Design

- Structural analysis
- Materials modelling
- Thermal and fluid dynamics
- Acoustic simulation
- Manufacturing process simulation

Production

- Production machining
- Mould & die design and manufacture
- Sheet metal fabrication
- CNC simulation
- Factory automation

Metrology

- (Hardware) Coordinate Measuring Machines
- (Hardware) Portable Measuring Arms
- (Hardware) Laser Trackers and Stations
- Statistical process control
- Dimensional inspection
- Automated inspection
- Metrology-assisted manufacturing
- Robot and machine calibration
- Non-destructive testing
- Reverse engineering

Hexagon's portfolio also includes a leading cloud-based Quality Management System (QMS) platform.

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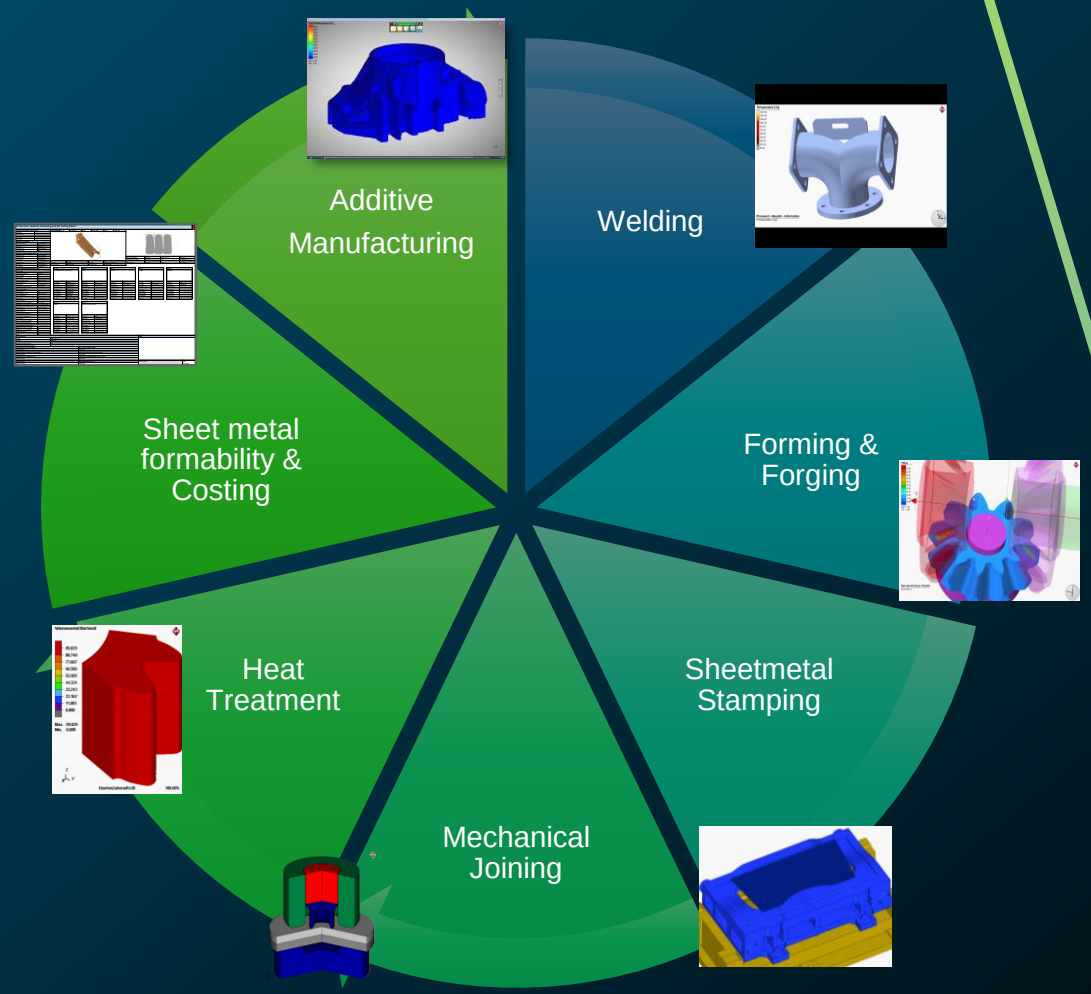

Customer Challenges : Virtual Manufacturing

Shorten Lead Time

Release new product to the market with the right timing and keep advantage over competitors

Reduce Prototypes

Reduce the number of physical prototype tests to reduce cost and save time

Reduce Rework

Detect and correct problems early in design and process development to reduce late-stage rework

Automation/Skill Transfer

Gather and share knowledge and experience to new staff, maintaining consistent high quality

Cost Control

Reduce raw material and rework costs and weight of designed product

Respond to Changes

Shifting the production system from mass production to small-lot, high-mix production to meet market needs.

- Optimize the Manufacturing Process
- Reduce Shopfloor try-outs
- Increase Material yield
- Define optimum Process parameter
- Decide stages in Manufacturing
- Light weighting of structures
- Reduce cost of component and assembly
- Increase life of tooling and components

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Virtual Manufacturing

Overview – Capabilities & Products

FTI FormingSuite | Simufact Forming | Simufact Welding | Simufact Additive | Digimat-AM | MSC Apex Generative Design

Cold Forming | Hot Forging | Sheet Metal Forming | Mechanical Joining

Rolling | Ring Rolling | Open Die Forging | Heat Treatment

Arc Welding | Laser Beam | Electron Beam

Resistance Spot Welding | Brazing | Stress Relief

Powder Bed Fusion | Binder Jetting

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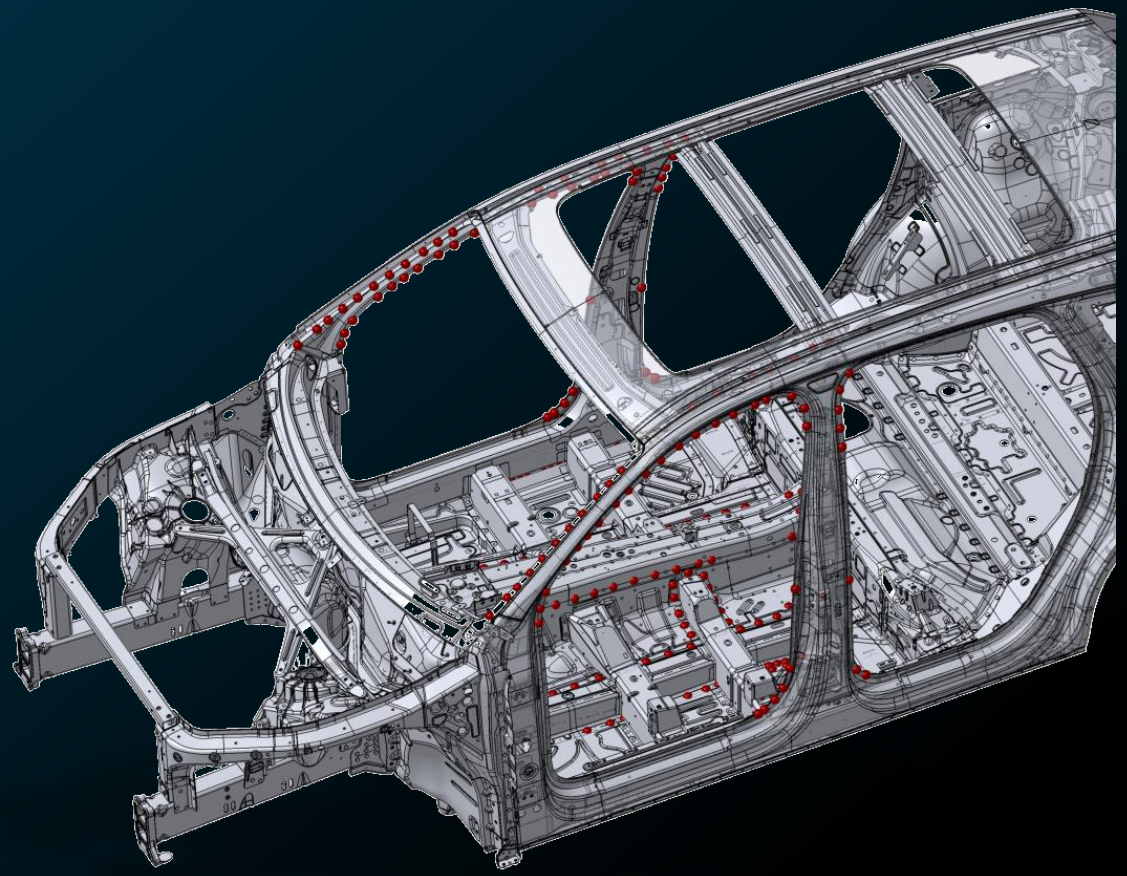
SIMUFACT JOINING SOLUTIONS

1. WELDING SOLUTIONS
2. JOINING METHODS FOR DIS-SIMILAR MATERIALS: FDS, RIVTEC,CLINCHING
3. DIRECT ENGERGY DEPOSITION



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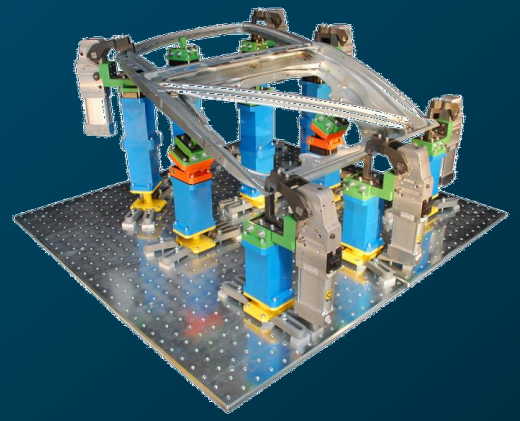
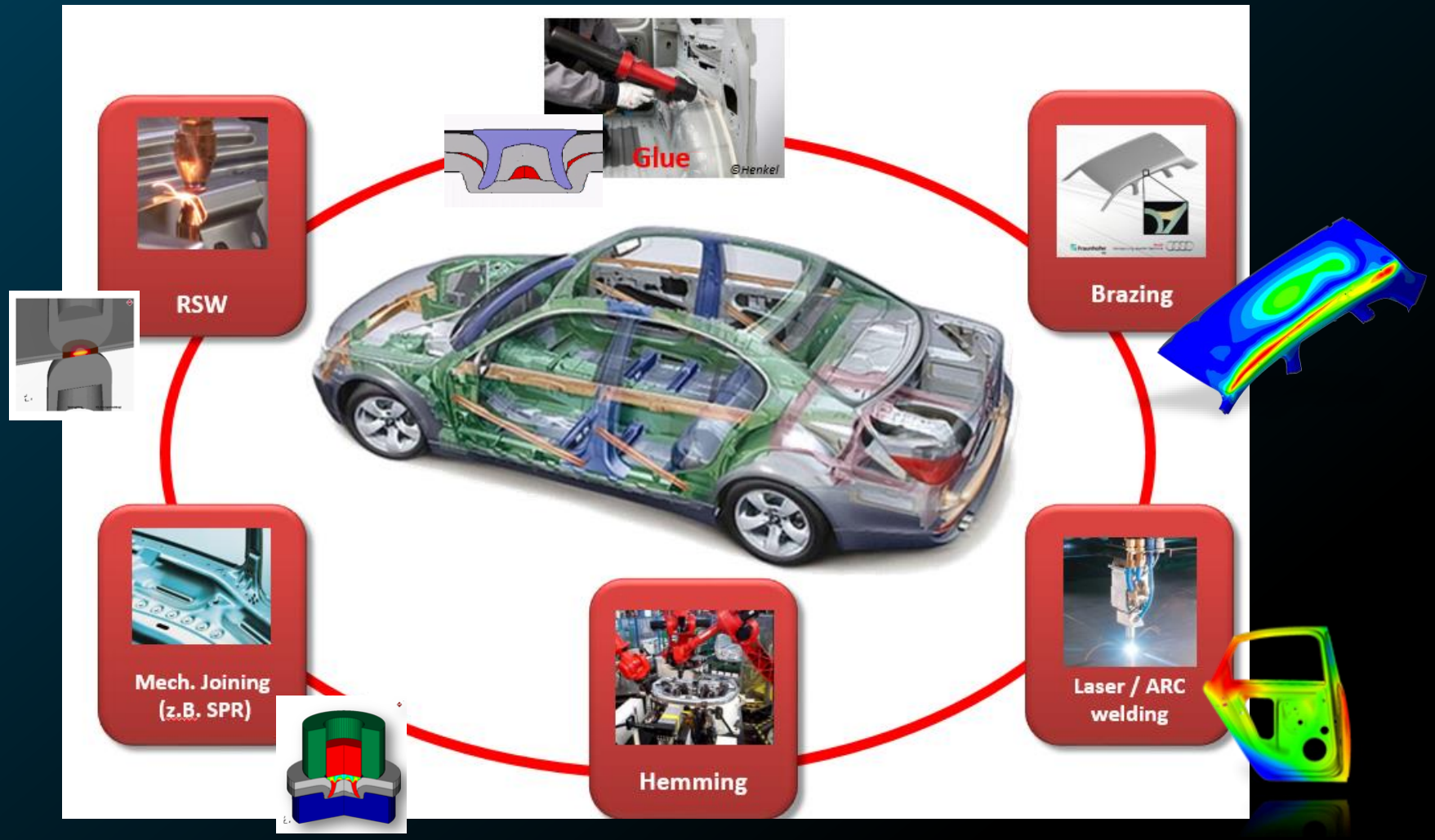
Assembly methods supported by manufacturing simulation



Clamping / De-clamping

Stress Relief



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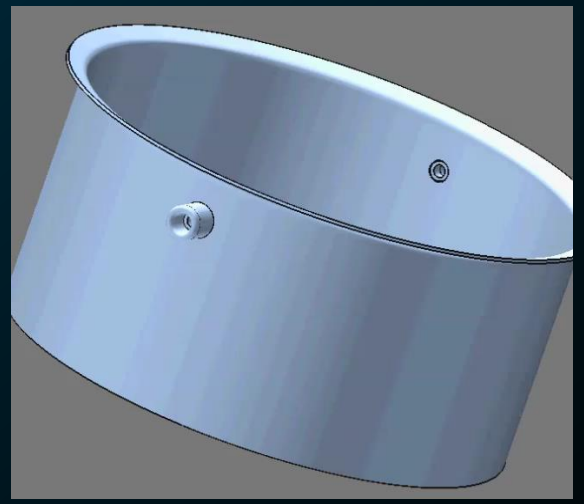
Why Simulation?

One physical try-out easily costs from some tens of thousands up to some hundreds of thousands of USD …

Save time and money by testing your ideas/process in a virtual environment



<u>During the design process</u>

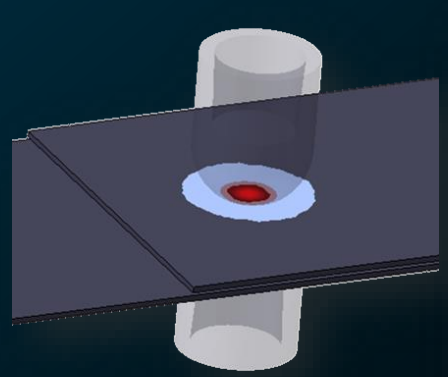
- Verify your design before shop floor try-out
- Identify problems
- Test new designs without which usually not tested because of short budget

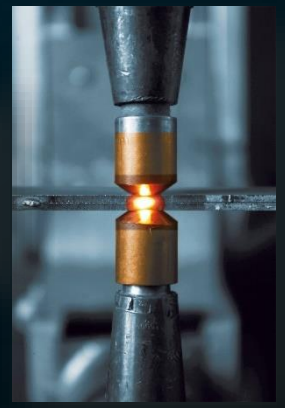
<u>During the manufacturing process</u>

- Investigate manufacturing problems
- Get a inside look into your process
- Optimize processes

<u>Benefits</u>

- Obtain information about assembly properties
  - Distortions
  - Residual stresses
- find suitable process parameters & fixtures
- Reduce unwanted deformations
  - Clamping concept
  - Weld sequence
- Reduce cycle times





Replace shop floor try-out

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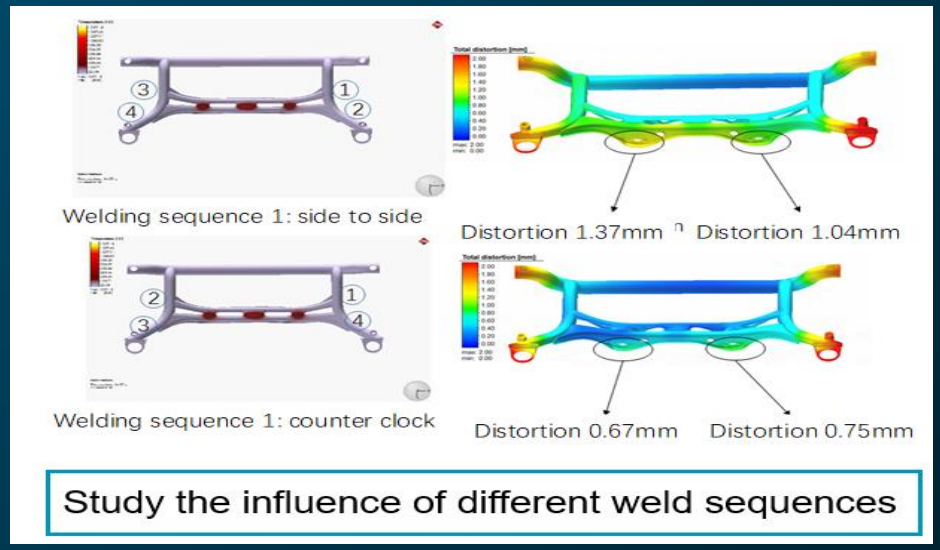
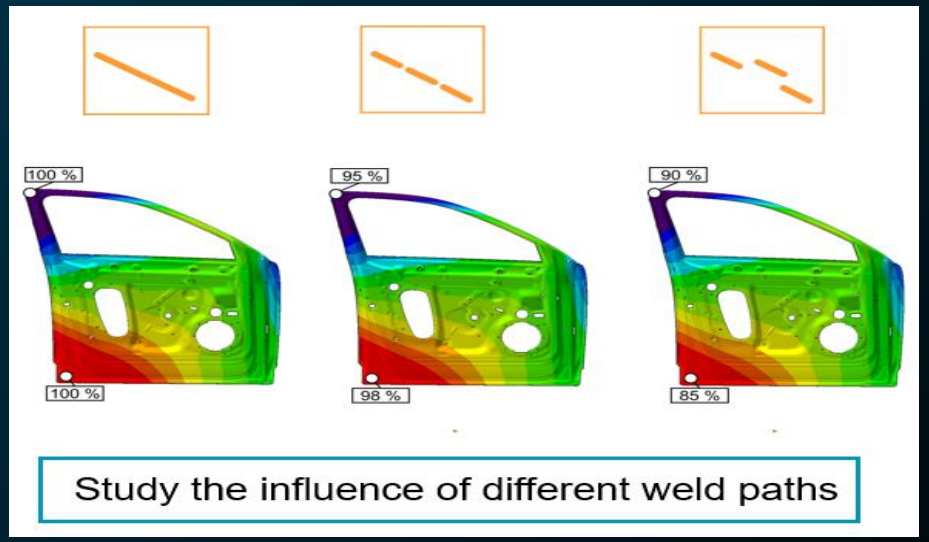
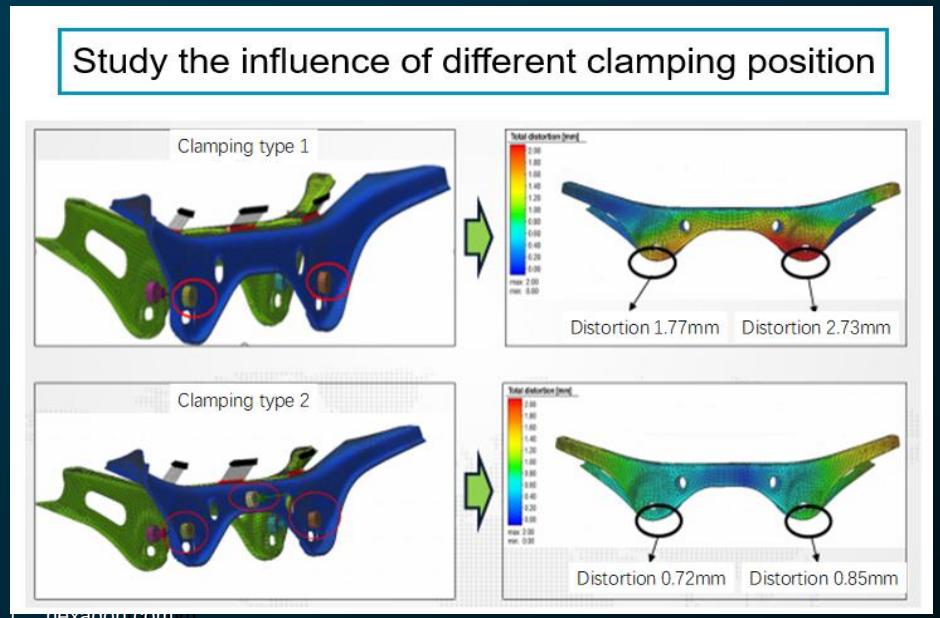
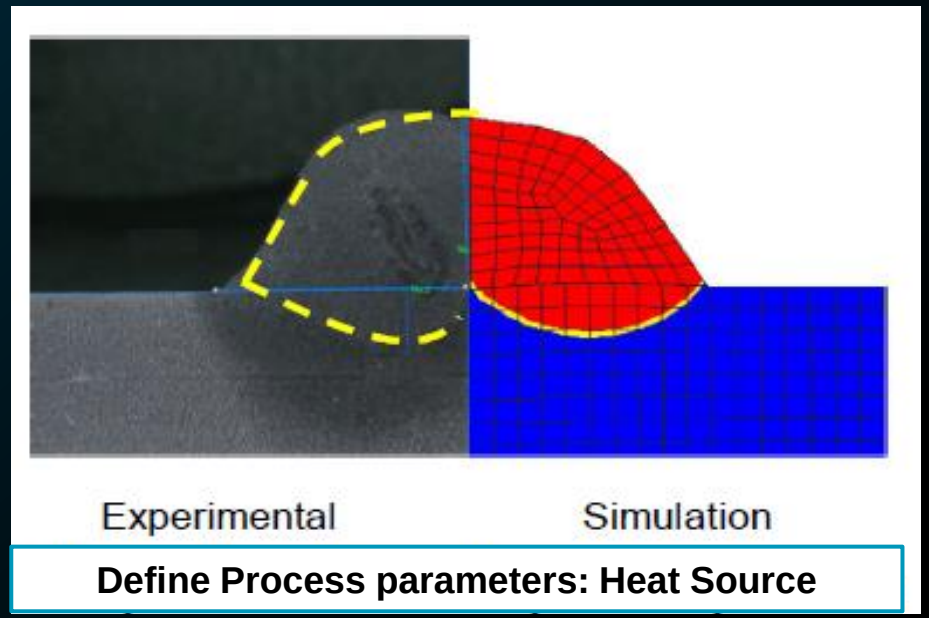
Potential Benefits of Welding Simulation









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Simufact Welding GUI

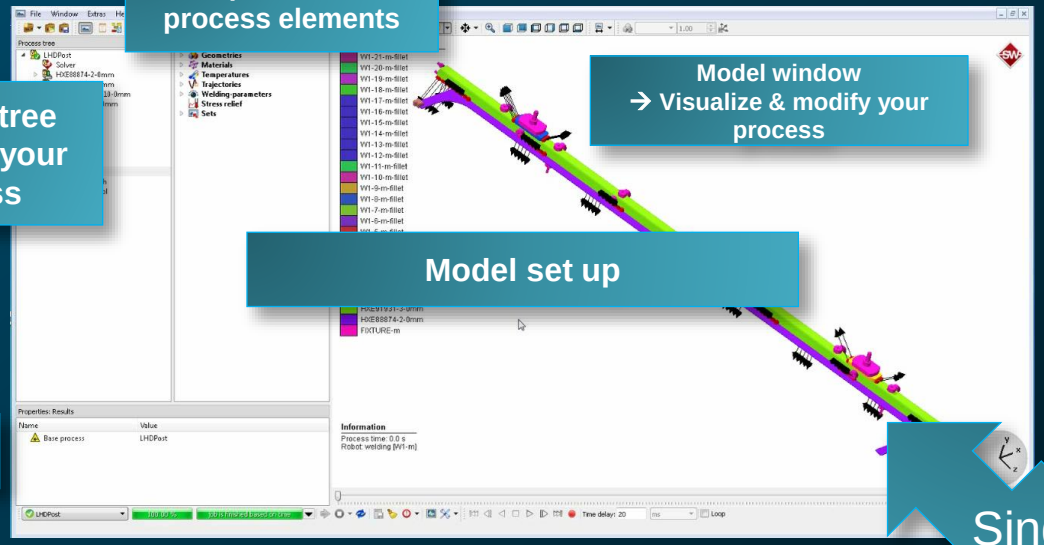
Object catalog
→ Import & create process elements

Process tree
→ Set up your process

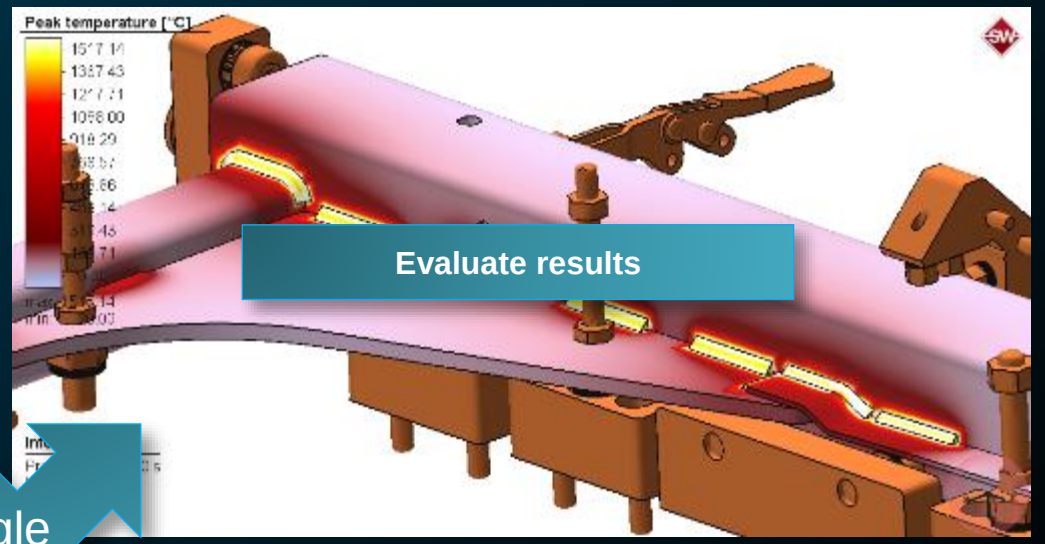
Model window
→ Visualize & modify your process

Model set up

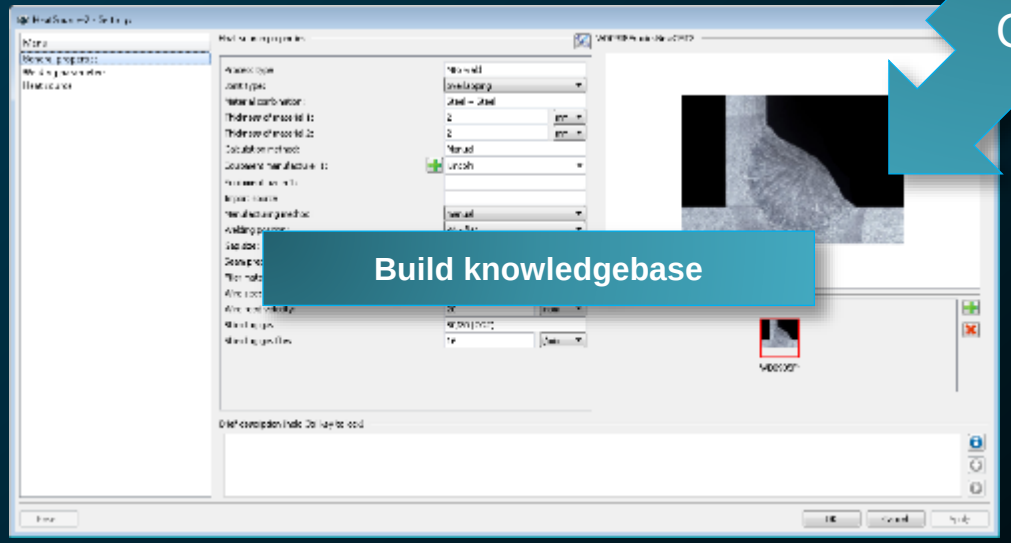
Process summary



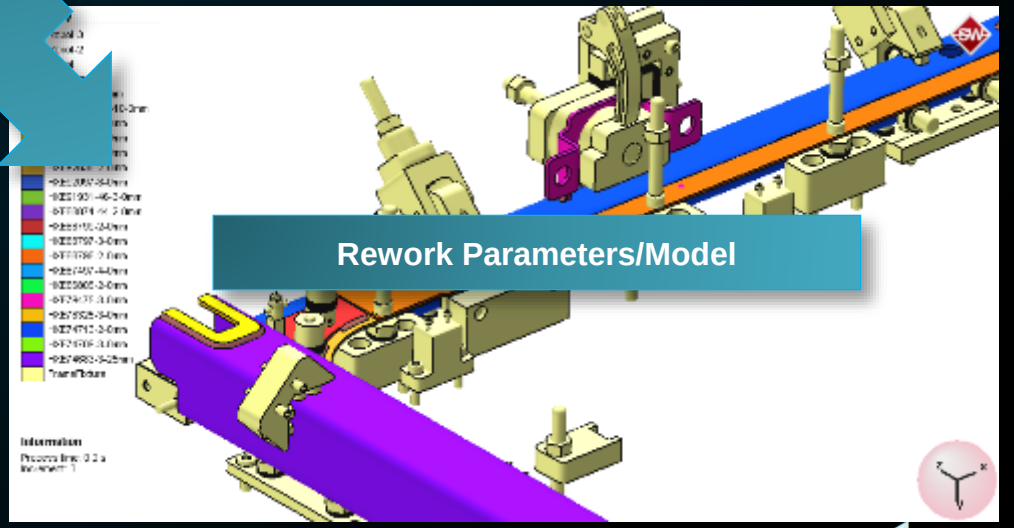
Single GUI



Evaluate results



Build knowledgebase



Rework Parameters/Model

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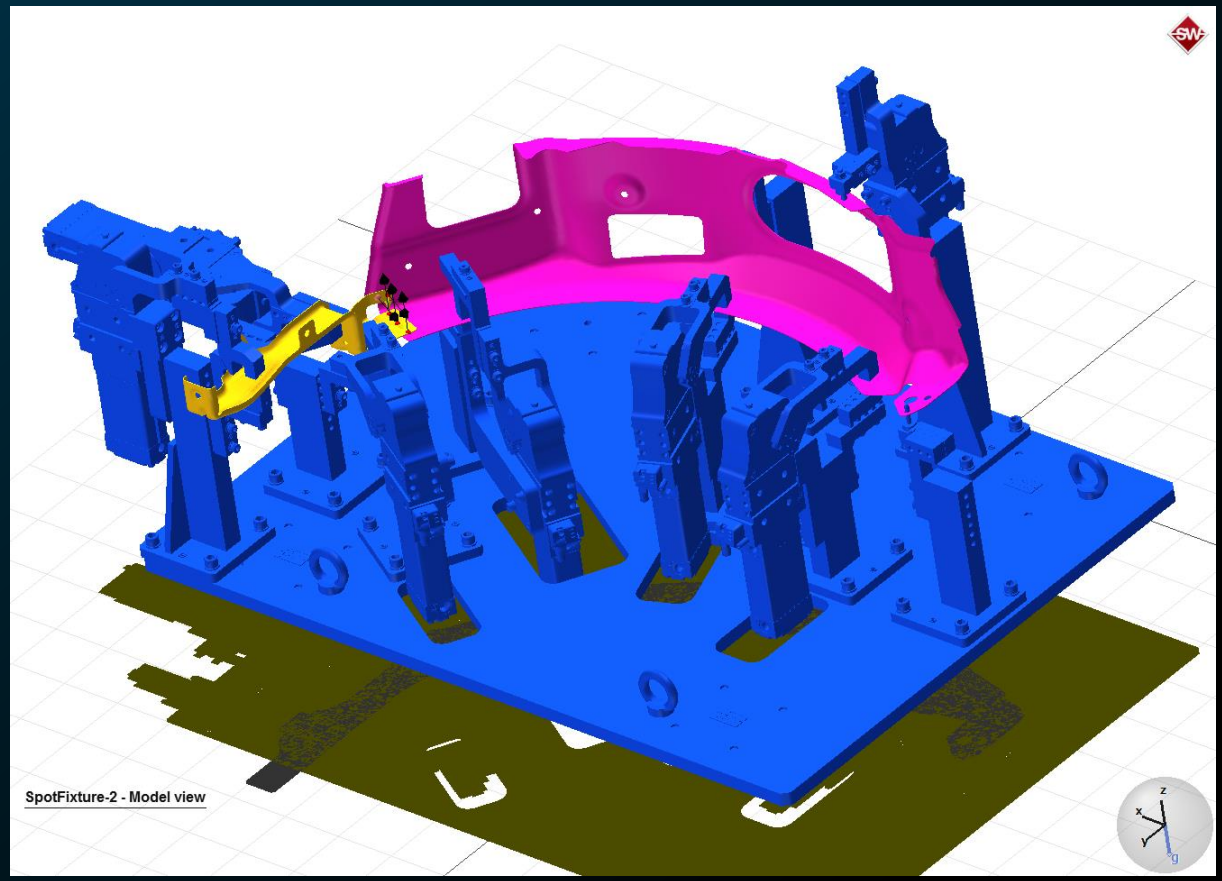
Resistance Spot Welding of a Wheelhouse

Material
- Wheelhouse: S235 (DIN St 37-3 N / AISI 1311
- Support: S235 (DIN St 37-3 N / AISI 1311)

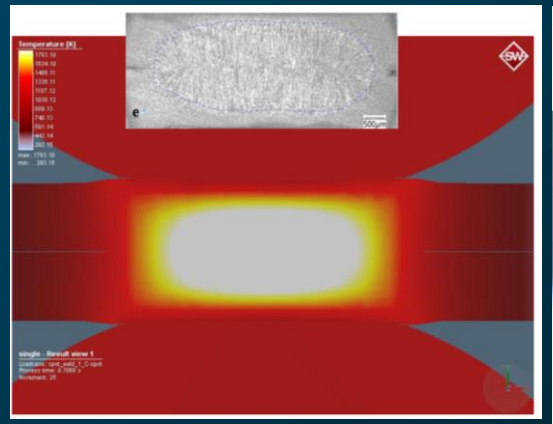
Mesh
- Fixture: 329k surface elements
- Wheelhouse: 47k solid-volume elements
- Support: 10k solid-volume elements

Parametrization
- 5 spot welds
- Electrode: G0-13-18-32-5-5 (ISO-5821)
- Gun force: 3500N
- Net frequency: 60Hz
- Squeeze time: 5 cycles
- Ramp-up: 2 cycles (0 – 8kA)
- Weld time: 12 cycles (8kA)
- Ramp-down: 2 cycles (8kA – 0)
- substages: 30 cycles @3500N



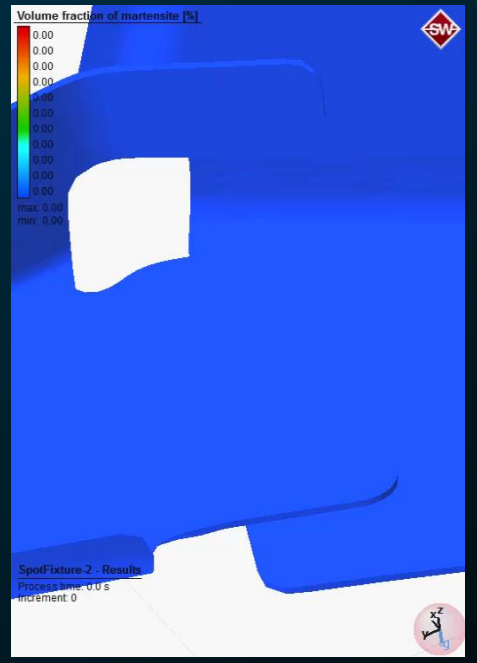
Resistance Spot Welding of a Wheelhouse

Weld Nugget Size

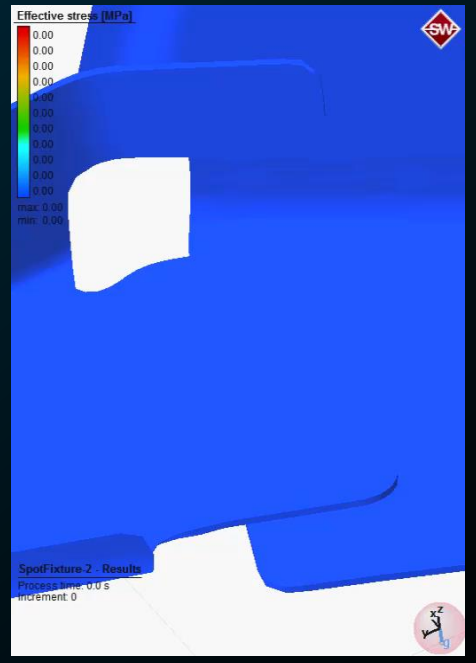


Temperature

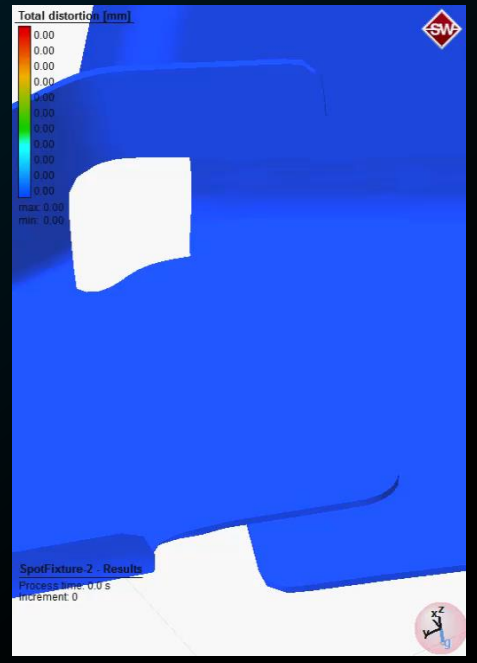
Phases



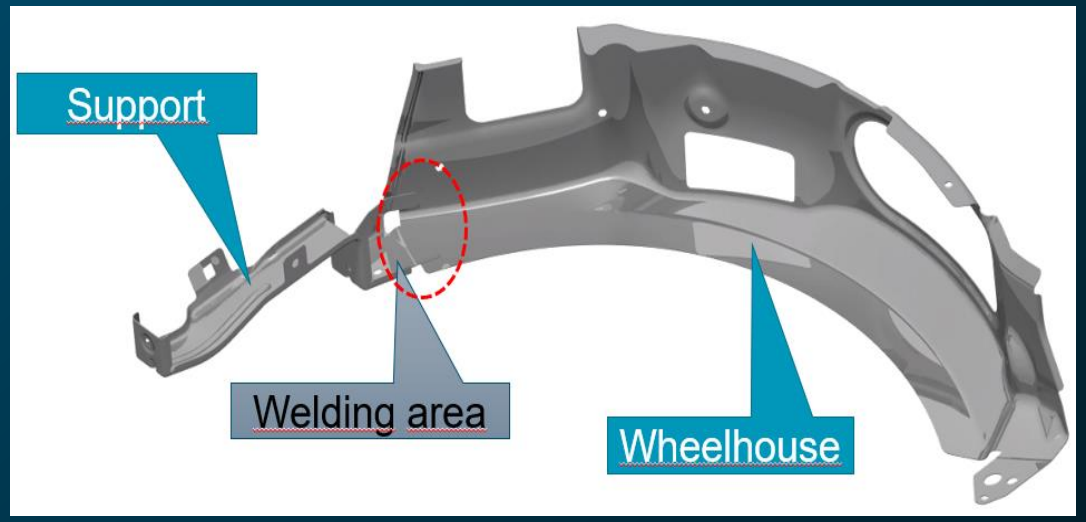
Stress

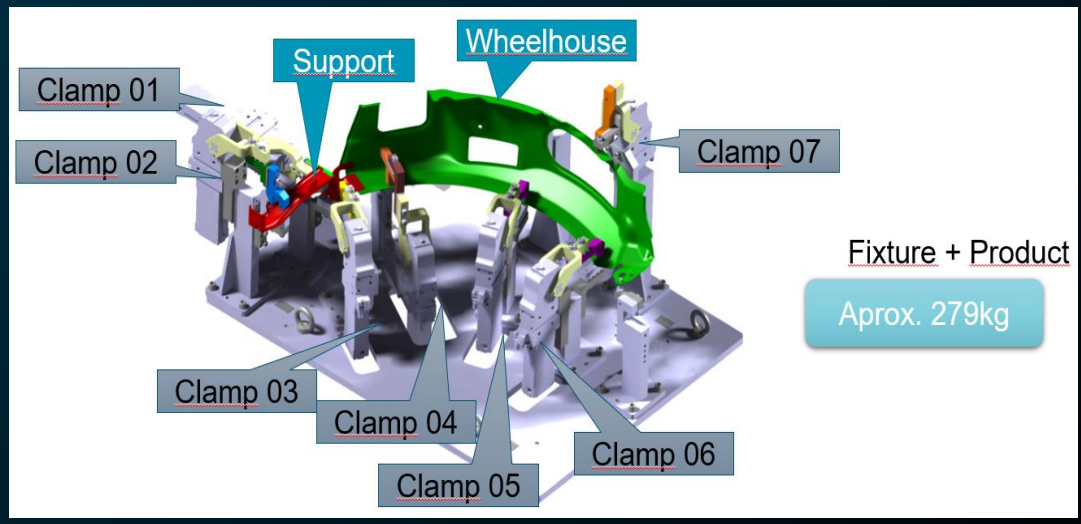


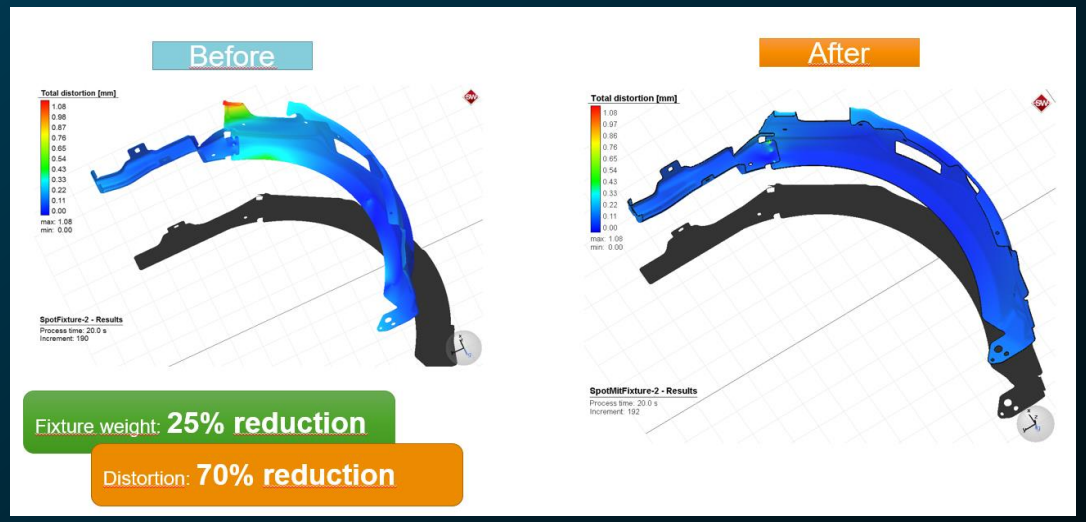
Distortion

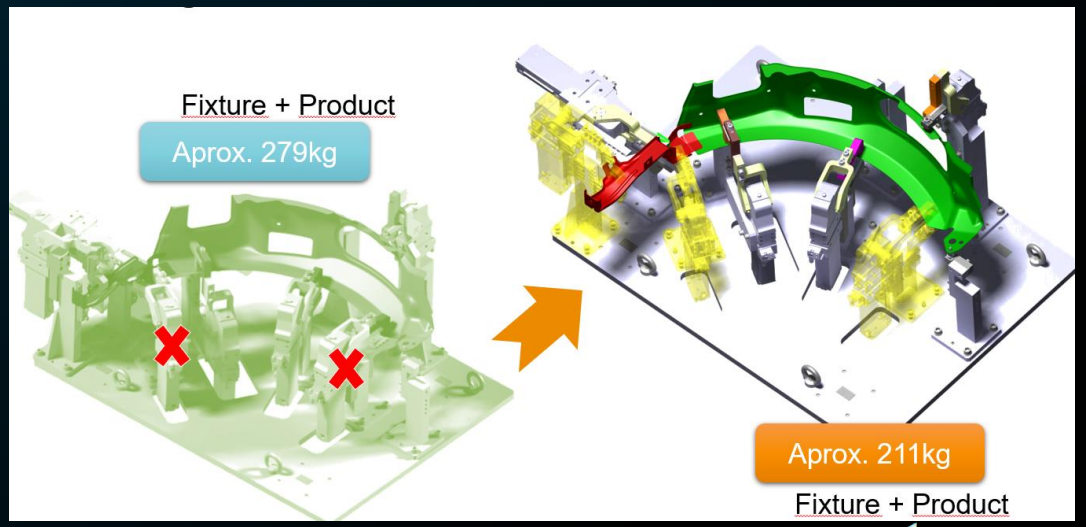


Resistance Spot Welding of a Wheelhouse









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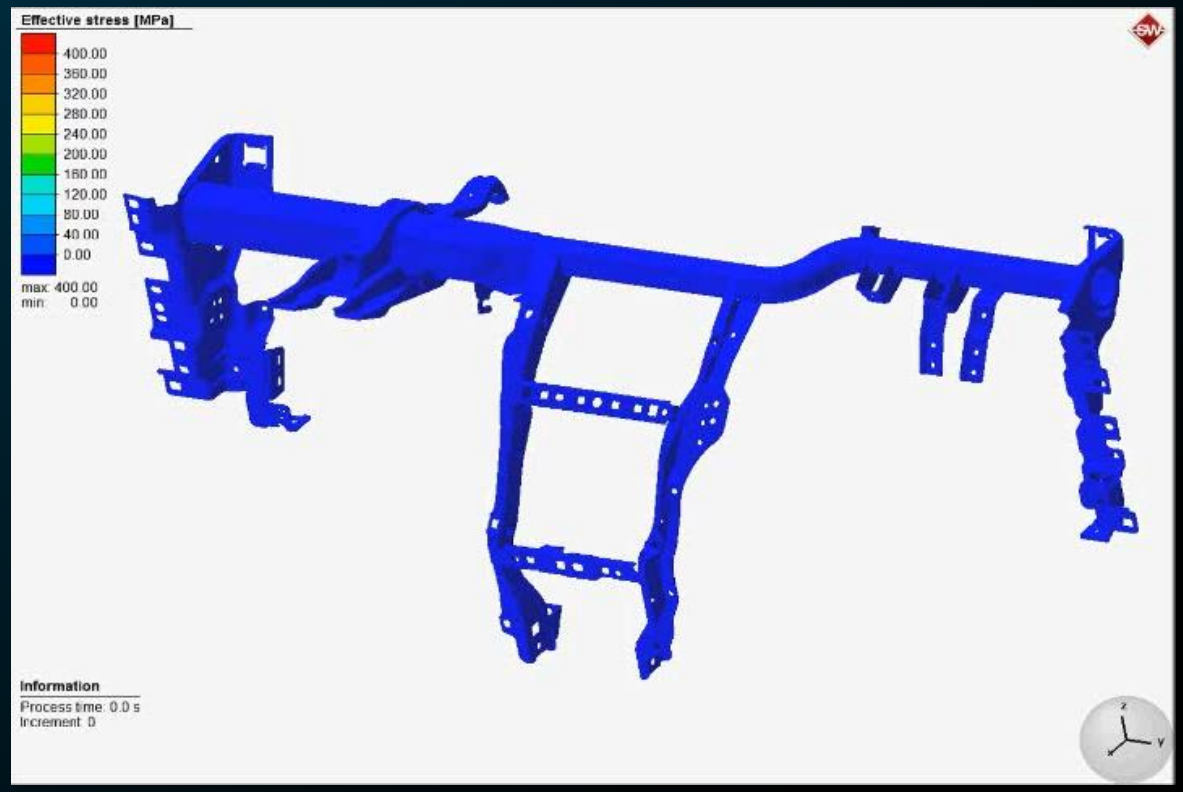
Arc Welding of a Car Cross Beam

Temperature



Equivalent Stress

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Laser Welded Car Door

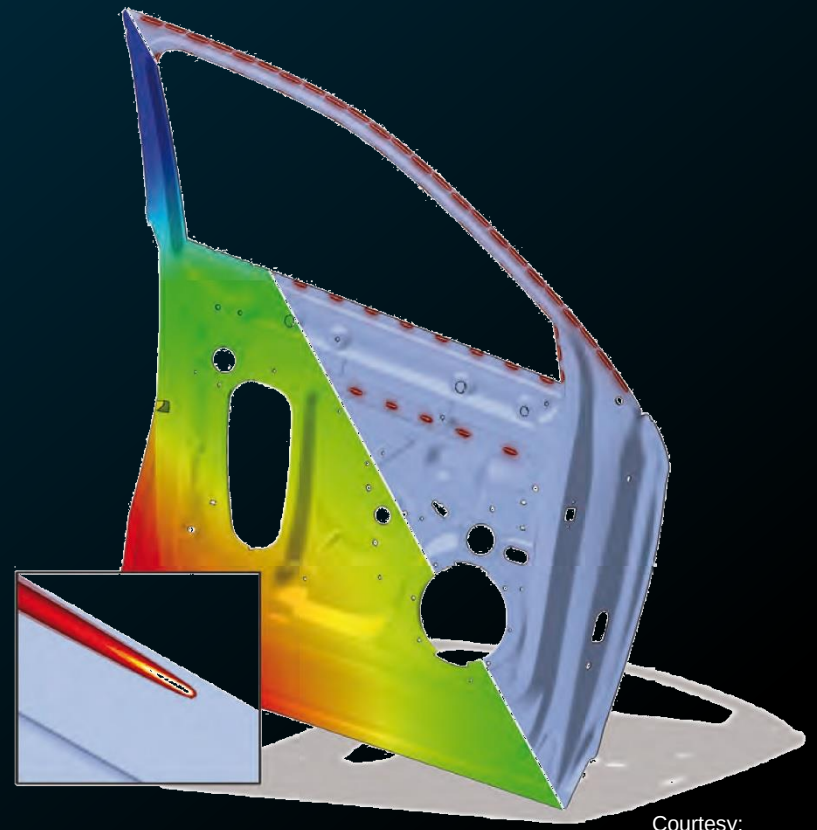
Enable virtual validation by leveraging laser welding simulation software

- Reduce process design/tryout costs and duration
- Improve welding process robustness
- Reduce risk in product development and launch process

Simulation Case Study

- Simulate Audi door assembly using remote laser welding
- Attempt to minimize distortion without physical tryout

Original Article can be found at:
http://onlinelibrary.wiley.com/doi/10.1002/latj.201500009/pdf
Wiley-VCH Verlag GmbH & Co. kGaA, Weinheim
Laser Technik Journal, 2/2015



Courtesy:

Fraunhofer IPK

Audi

Vorsprung durch Technik

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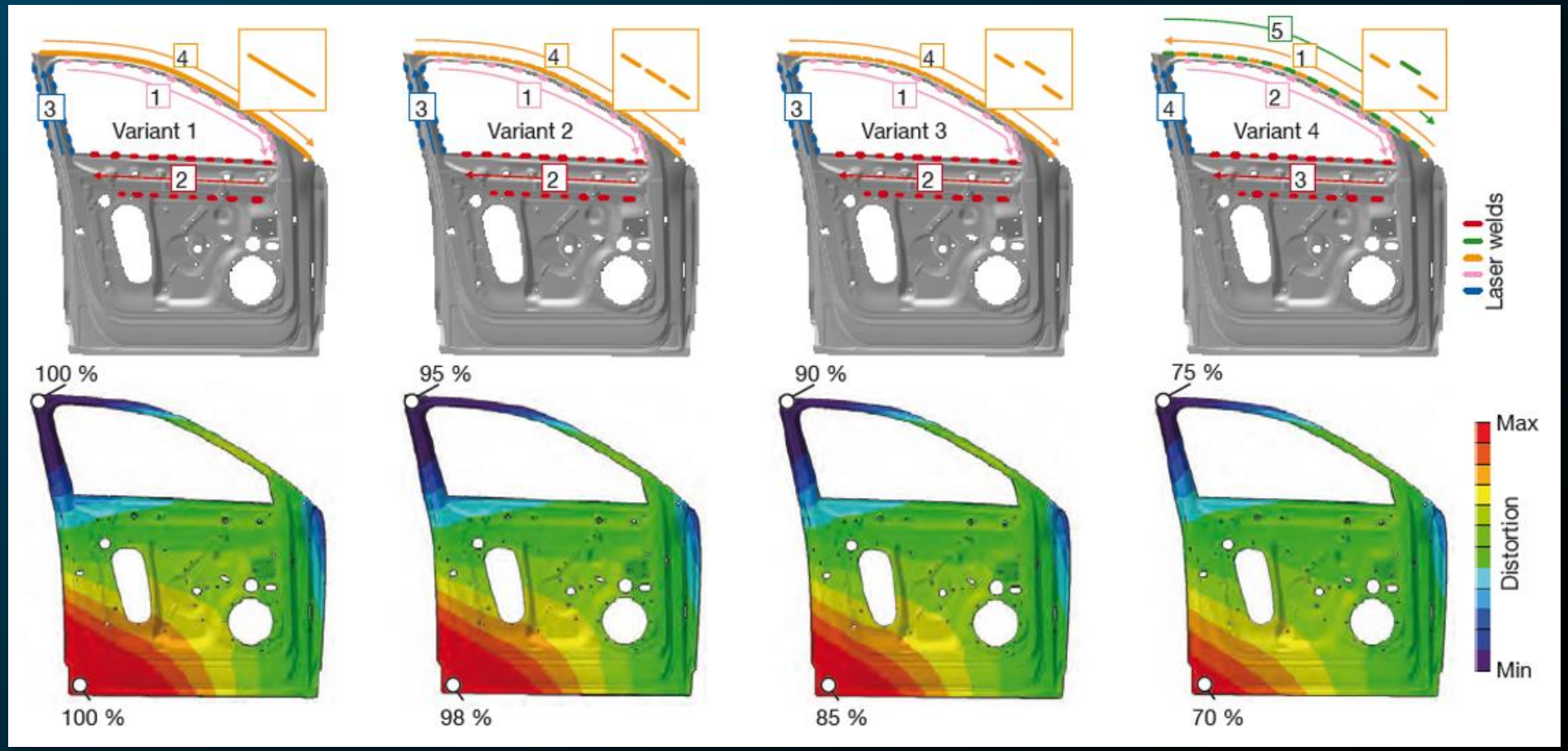
Laser Welded Car Door



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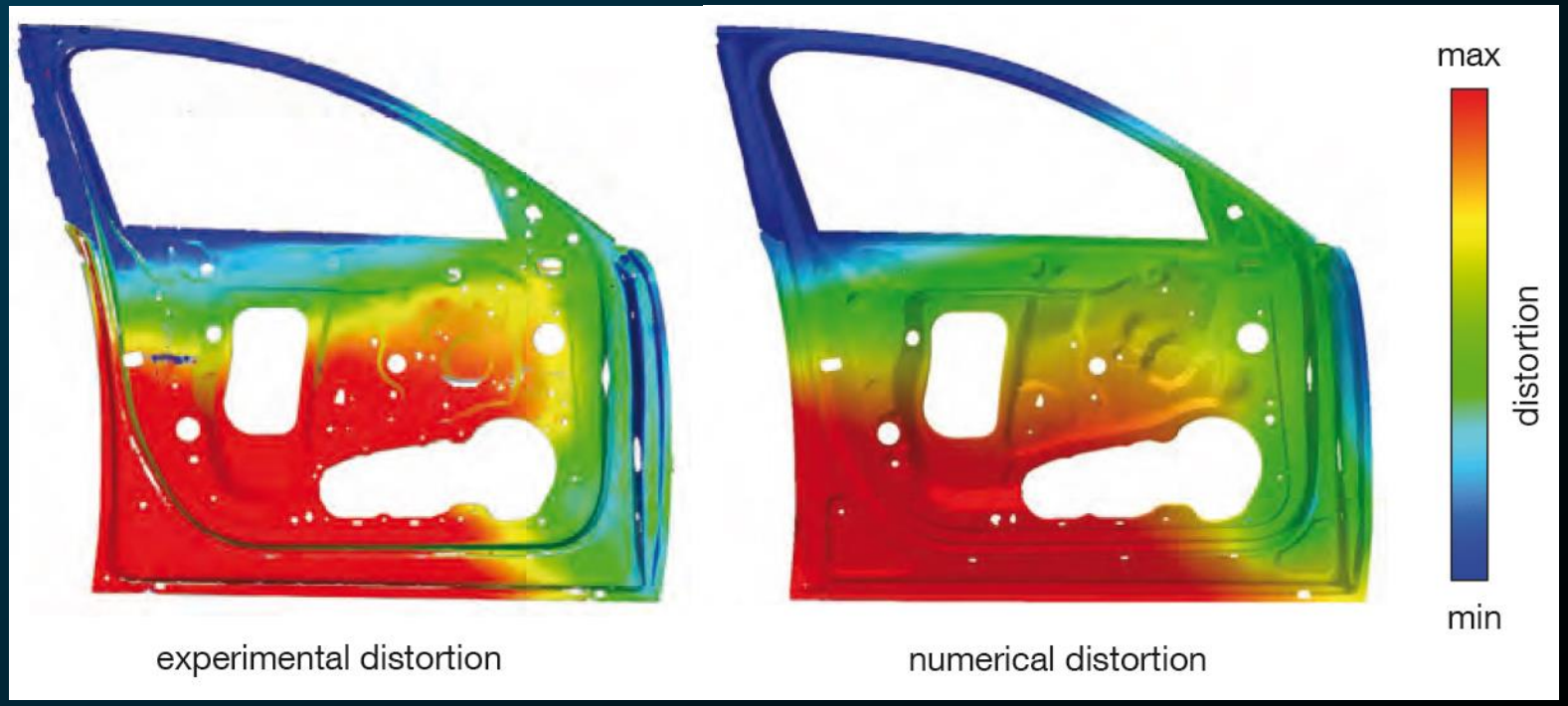
Laser Welded Car Door

Comparison between experimental and simulated distortion

- Agreement in trend and magnitude of distortion

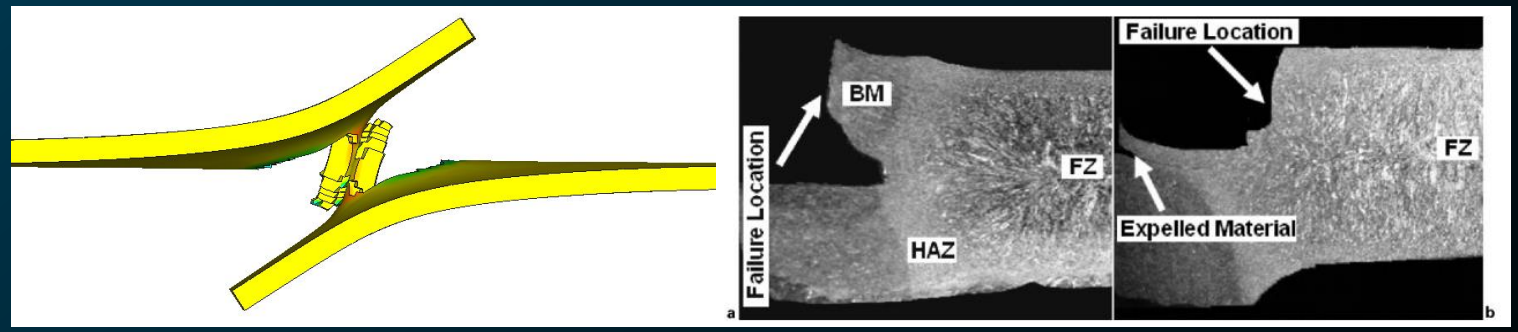


Physical Tryout
Experimental Results

Virtual Tryout
Numerical Results

Virtual Welding & Testing

Summary of results



Material	Force (kN)			Displacement (mm)		
	Experim.	Simulation	Deviation	Experim.	Simulation	Deviation
DP600	16.5	15.9	3.8%	2.55	2.65	3.9%
Q235 1mm	8.3	8.4	1.2%	1.85	1.97	6.0%
Q235 1.5mm	14.3	15.3	7.0%	2.10	2.21	5.2%
PHS 22MnB5	18.5	19.3	4.3%	0.68	0.63	8.0%

- We are simulating the cracking phenomena (phenomenological approach, not grounded theory approach)
- All simulations were performed with the same damage parameters (JC model)

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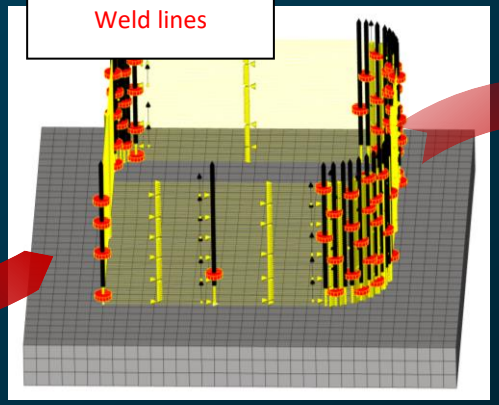
DED -Workflow

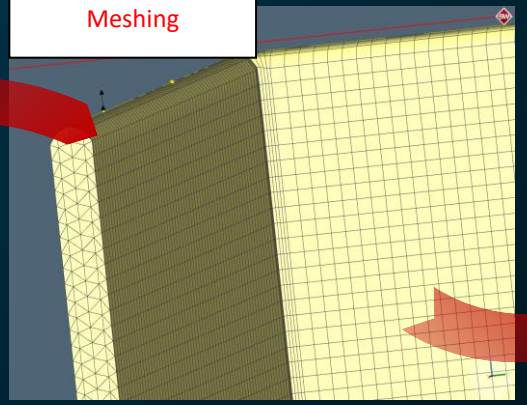
G-Code

```
835 E0.008
G1 X42.884 Y0.835 F9000
G1 E2.05 F1200
G1 X42.884 Y1.088 E0.008 F3840
G1 X67.204 Y1.088 E0.7684
G1 X67.204 Y0.835 E0.008
G1 X42.884 Y0.835 E0.7684
G1 X42.884 Y-0.498 E0.0421
G1 X67.204 Y-0.498 E0.7684
G1 X67.204 Y-1.831 E0.0421
G1 X42.884 Y-1.831 E0.7684
G1 E-2 F1200
```

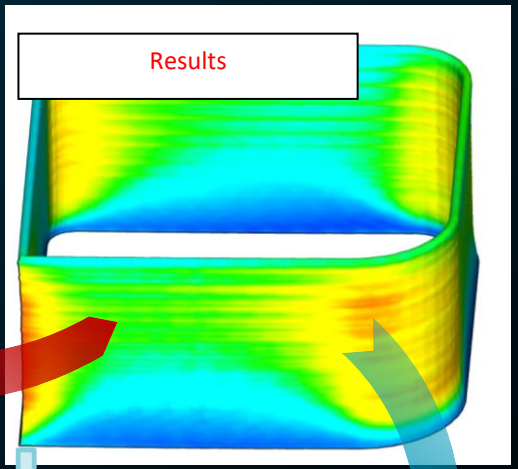
Weld lines



Meshing

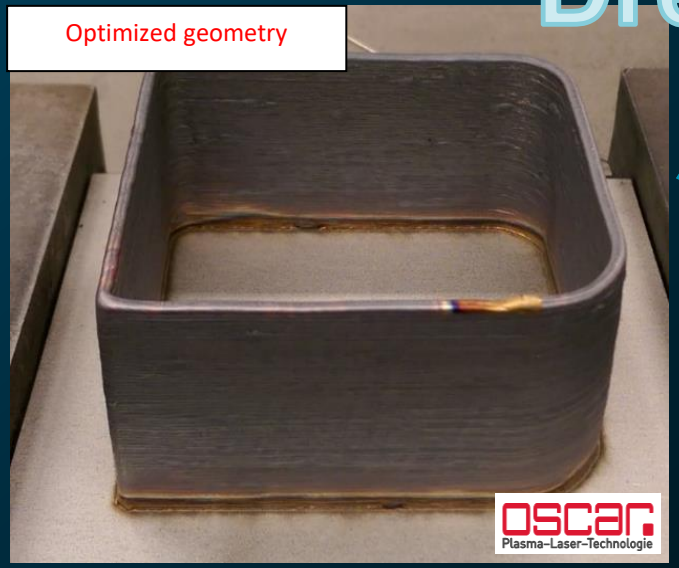


Results



Dreams of the future !

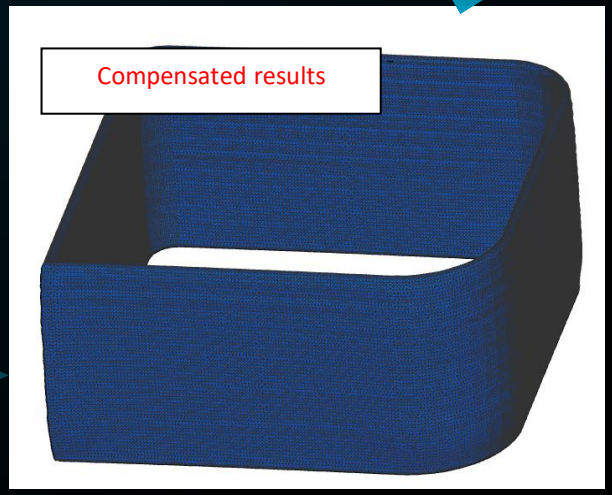
Optimized geometry



New G-Code

```
835 E0.008
G1 E-2 F1200
G1 X42.884 Y0.835 F9000
G1 E2.05 F1200
G1 X42.884 Y1.088 E0.008 F3840
G1 X67.204 Y1.088 E0.7684
G1 X67.204 Y0.835 E0.008
G1 X42.884 Y0.835 E0.7684
G1 X42.884 Y-0.498 E0.0421
G1 X67.204 Y-0.498 E0.7684
G1 X67.204 Y-1.831 E0.0421
G1 X42.884 Y-1.831 E0.7684
G1 E-2 F1200
```

Compensated results



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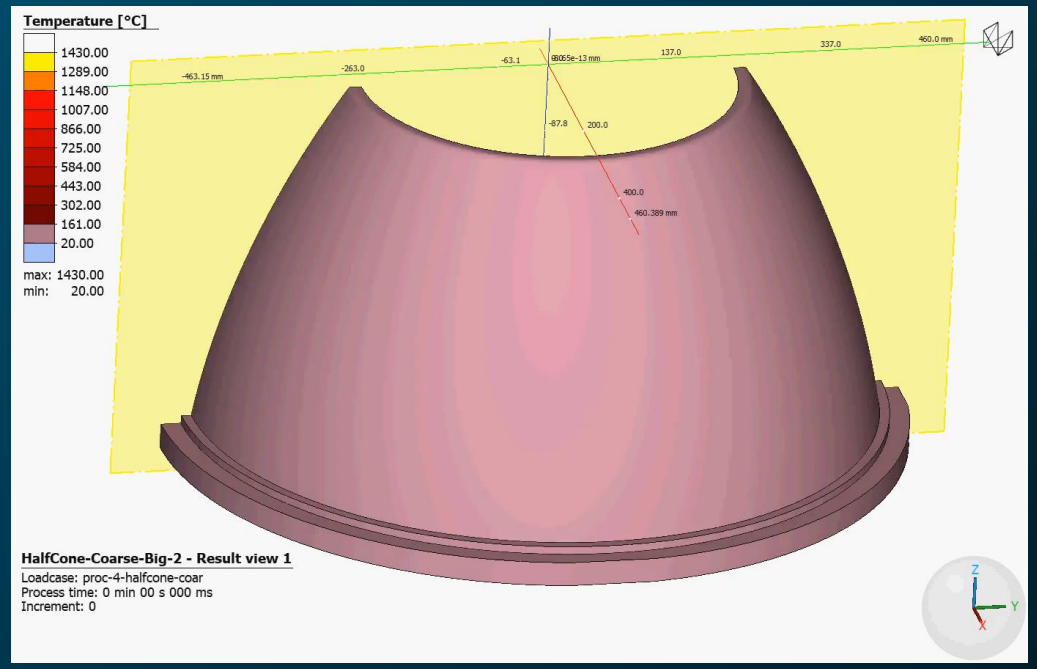
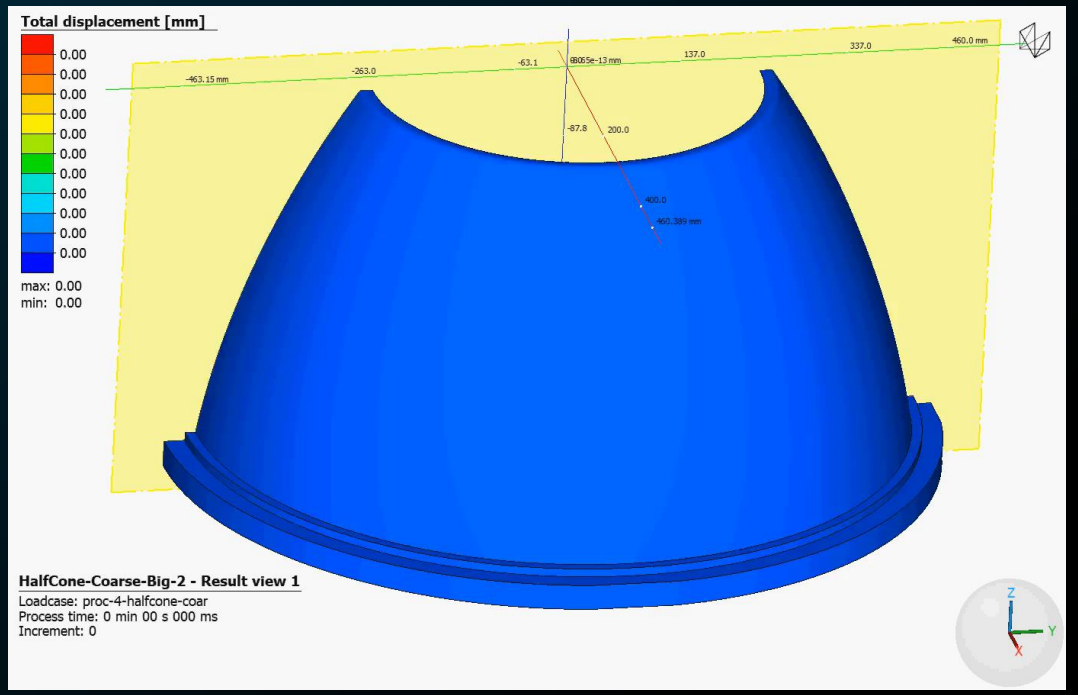
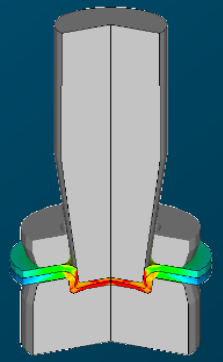
DED- distortion compensation

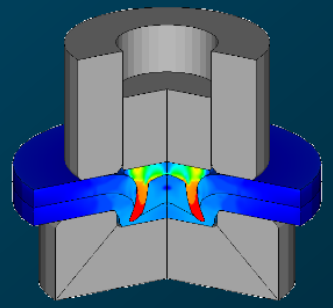




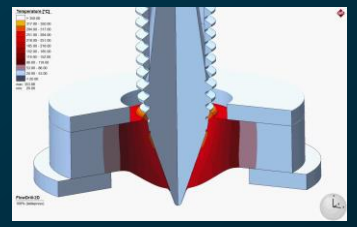
Mechanical joining



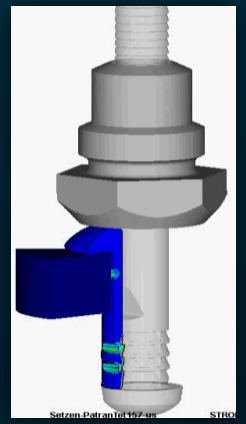
Clinching



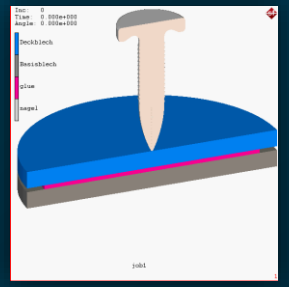
Self pierce riveting



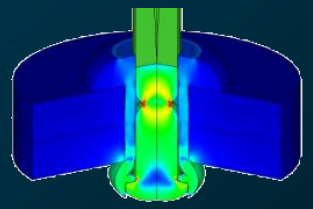
FDS



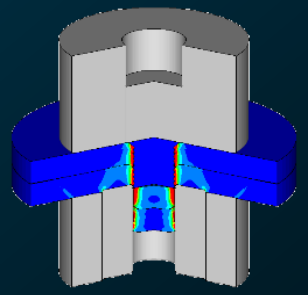
Lockbolt



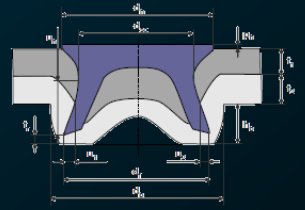
Rivtac®



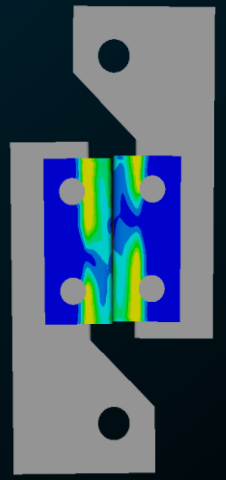
Blind riveting



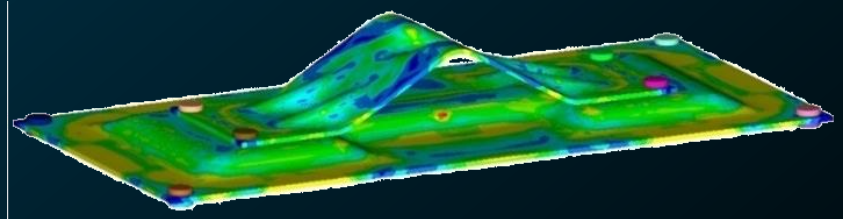
Punch riveting



Results examination



Destructive testing



Riveting of 3D structures

Consideration of:

- elastic and plastic effects
- thermal effects and joule heating
- damage
- adhesive

- Use of 2D axisymmetric elements, 3D tetrahedron or brick elements
- Simulation time starting from 5-10 minutes for 2D applications

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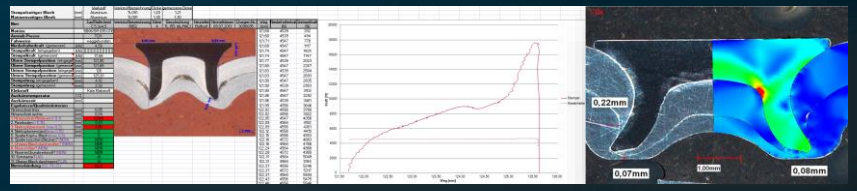
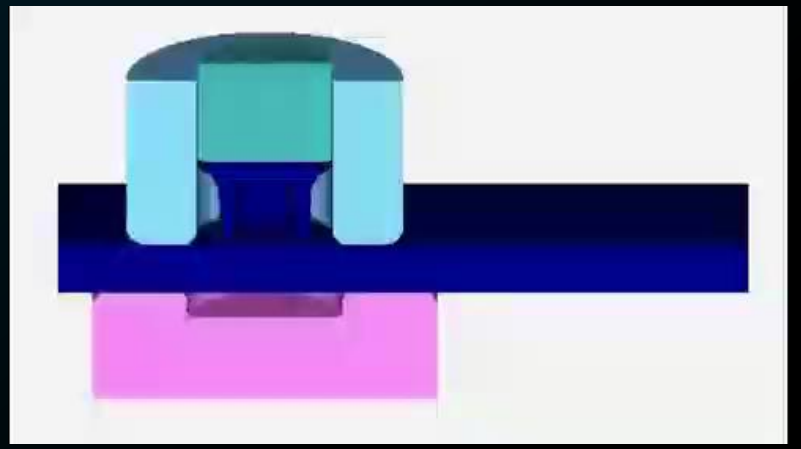
Assembly application – mechanical joining

Reduce expensive physical testing !

- Find suitable connection parameters:
  - Rivet/clinching type
  - Die geometry
  - Process parameters
- Obtain information about joint strength
- Optimize joining sequence w.r.t. overall distortion





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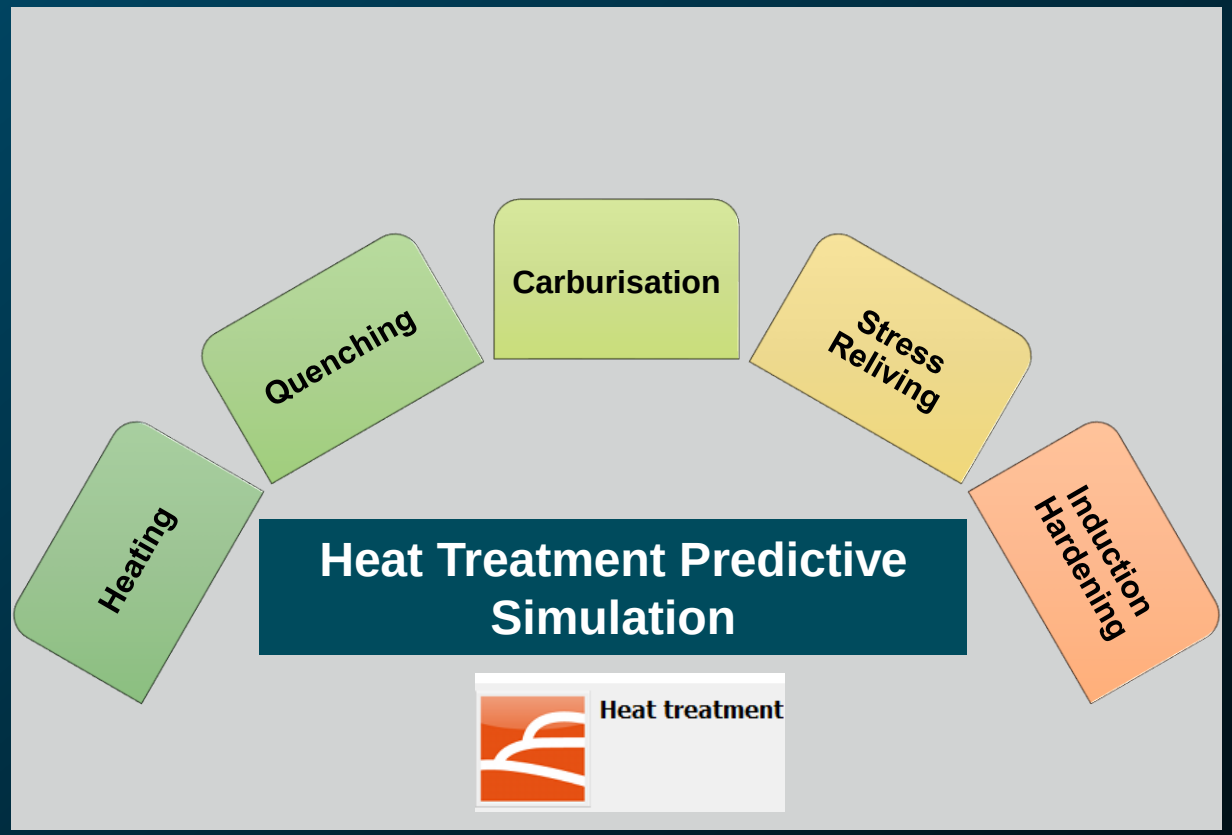
Heat Treatment Solution

What we can simulate……



Is the selected heat treatment process feasible?

Is the selected steel feasible?

Is the selected quenching media suitable?

Is the process window safe against process tolerances?

Is the part hard where it should be hard?

Is there any crack risk occurring during the process?

Are the obtained distortions acceptable?

Are the residual compressive stresses high enough and well positioned?

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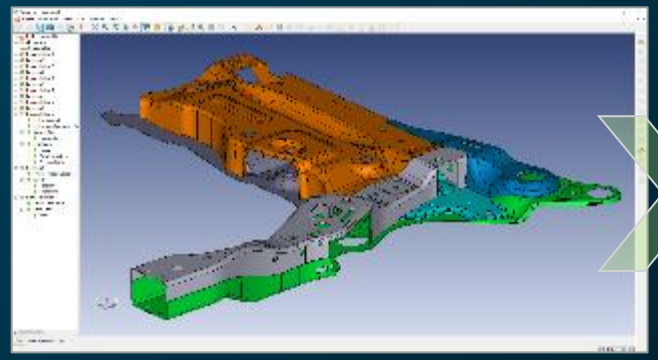
Advance technologies to manufacture components

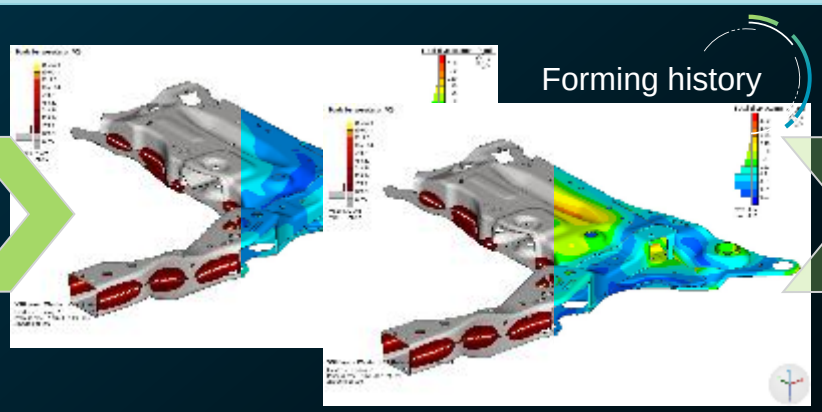
Chaining Simulations

Breaking silo'ed simulations to enable 'single point of truth'

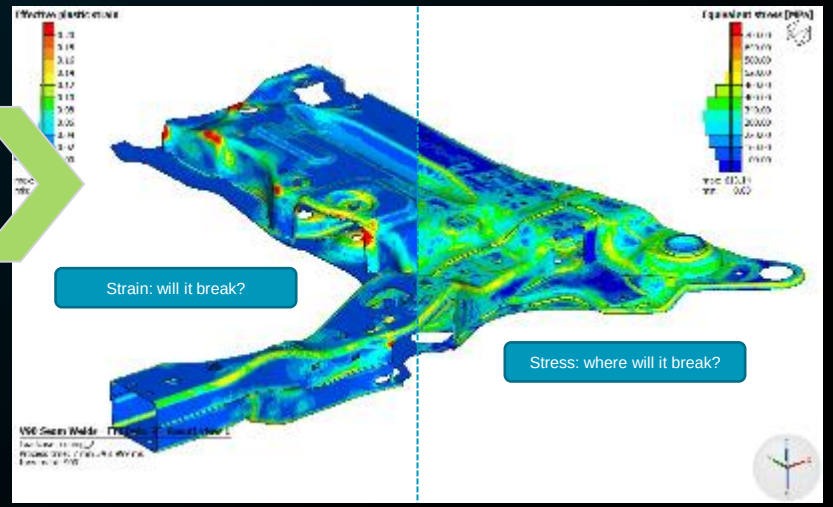
Formability



Welding & Assembly



Improving part design



Simulation tools must be able to talk to each other

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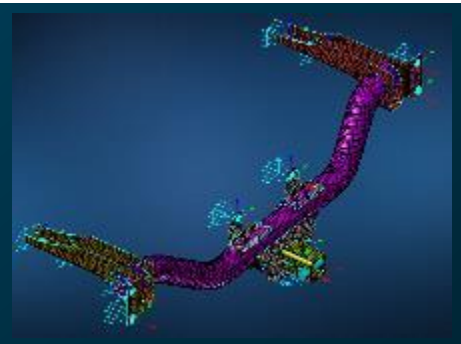
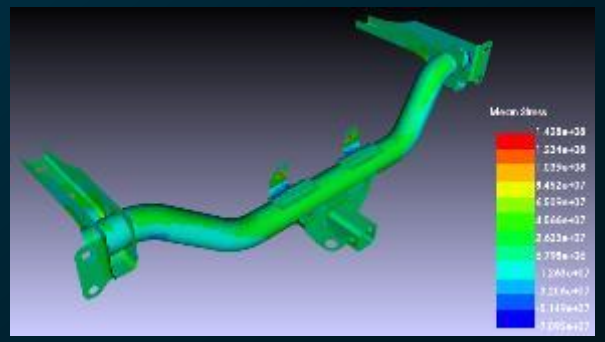
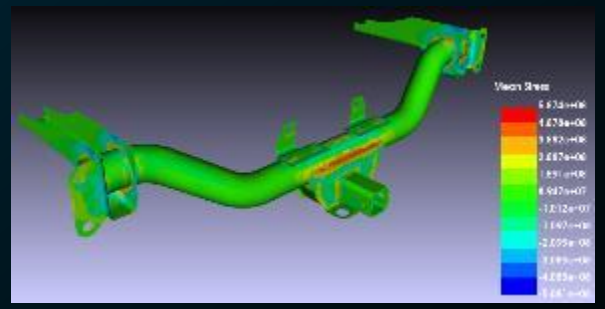
One step further: from structural to fatigue

You have the data, let’s transform it into knowledge!

	Structural Model Only	Mean Stress [Pa]	Fatigue Life [Cycles]
Without residual stresses			
With residual stresses			

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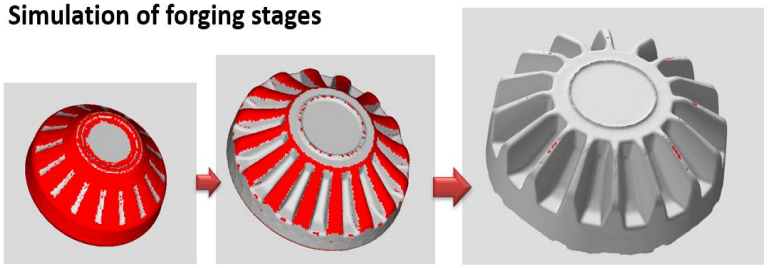
Manufacturing Simulation: Stress Mapping

Simufact provides end to end solution to the gear manufacturers

Forming → **Heat Treatment** → **Welding**

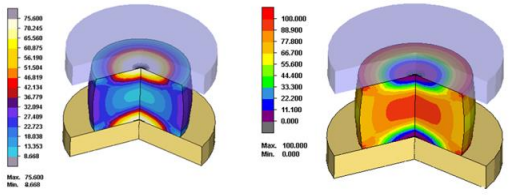
Simulation of forging stages

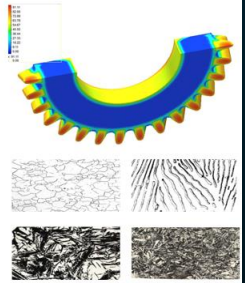


Helps you to detect w/o physical try-outs:

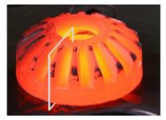
- Under-fill issues
- Folds, laps
- Tolerance issues
- Machine overload
- Die stresses & die wear
- Properties of forged component

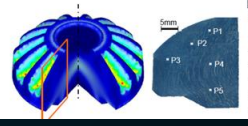
Simulation of heat treatment





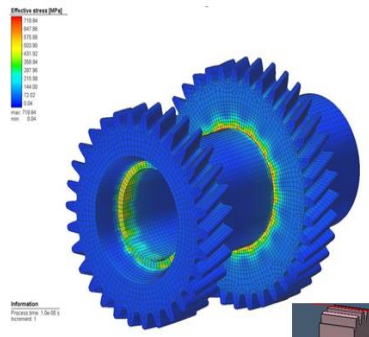
- JMAK-based solution algorithm
- Data input: CCT/TTT diagrams
- All mechanical/thermal properties phase dependent
- Phase fractions, distortions
- Grain size
- Case depth

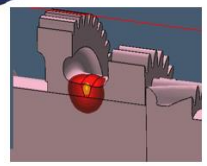


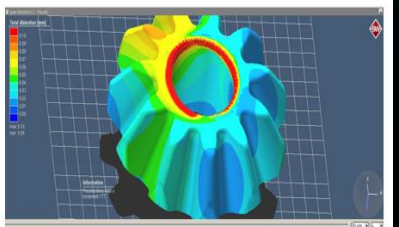


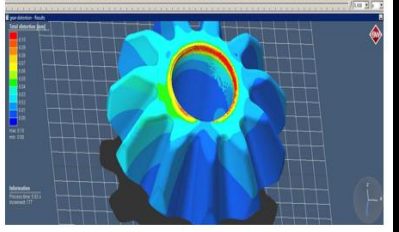
	Measured grain size in µm	Calculated grain size in µm
P1	12,3	13,6
P2	12,8	11,2
P3	12,6	10,2
P4	15,2	12,9
P5	14,2	13,4

Simulation of assembly - welding









- Laser welding
- Beam welding

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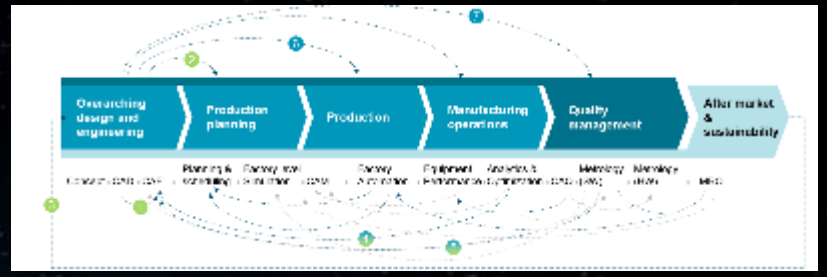
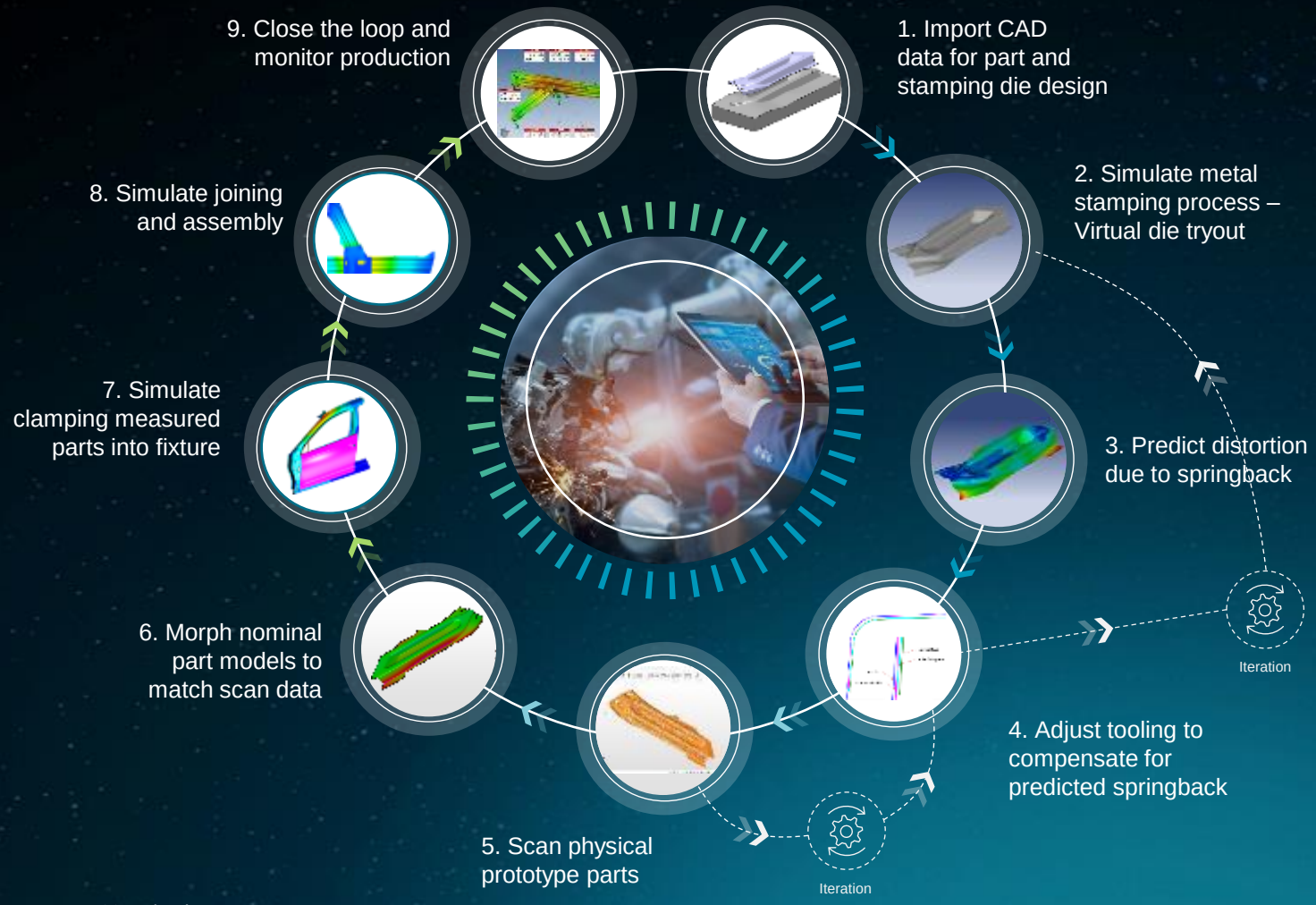
Smart Press and Assembly Shop

As Manufactured - True Integration of Virtual & Physical World





- True integration of Virtual and Physical World, enabling shift to zero prototypes, more sustainable manufacturing
- Prediction, feedback & Corrective actions real time
- Nexus enabled across MI solutions (D&E, Volume Graphics, Production & Metrology Software), addressing industry challenges holistically
- First addressable market – Automotive. MVP targeting February 2023

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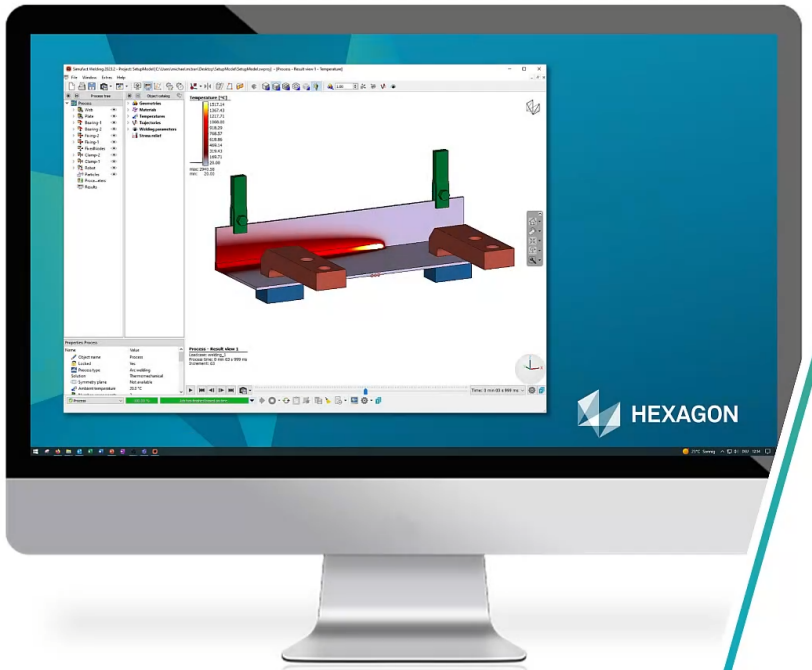
Virtual Manufacturing

Virtual Try Out | Welding & Assembly Simulation – Simufact Welding



Simufact Welding

Setup a Welding Process

under 1 Minute

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CAPABILITIES

- Arc Welding
- Laser Beam
- Electron Beam
- Direct Energy Deposition
- Resistance Spot Welding
- Brazing
- Testing & Stress Relief
- Cooling & Clamping

FEATURES AND BENEFITS

- Dedicated GUI simplifies and accelerates welding process modelling
- Model process mirrors setup on the shop floor
- Robustly handle large multi-station assemblies
- GUI is designed to replicate the shop floor with integrated pre/solve/post in one environment

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empowering an autonomous future

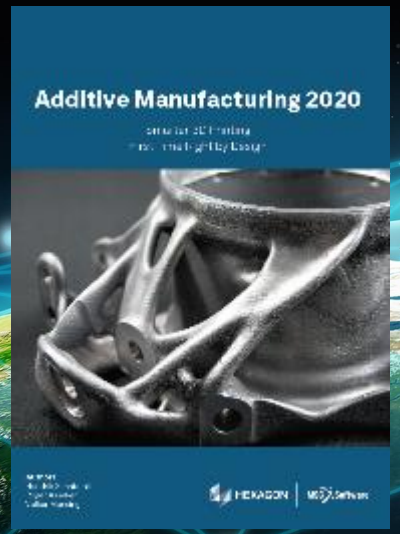
Thank you.

Further information available at [HxGN Virtual Manufacturing solutions | Hexagon]

Get to know….

White Paper

More



eBook

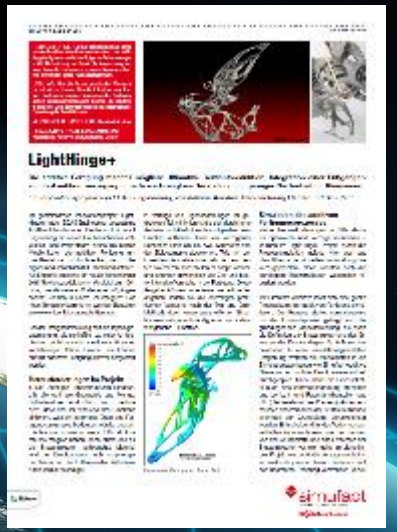
More

Case Study

More

Case Study

More



Case Study

More

Simulation for Saving Costs and Time

HxGN
Virtual Manufacturing

Summary

Virtual Manufacturing

Powered by Marc and Dytran, a suite of software solutions designed to simulate metal manufacturing processes, empowering manufacturers and engineers to optimise design for manufacturing, improve quality, and reduce time to market ultimately realise ‘Shift to Zero’.

1 World Class Accuracy
Physics-based simulation, account for all manufacturing variabilities, ensuring precision and reliability.

2 Ease of Use
User-focused design mirroring manufacturers’ workflows, making the software intuitive and easy to navigate.

3 Modular Approach
Separate modules for different manufacturing processes, with possibilities to connect relevant components for a more comprehensive process chain when needed.

Santosh Ner
Senior Manager, VMC Product ,India, ASEAN, ANZ
Design and Engineering business unit
Manufacturing Intelligence Division
Hexagon

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