10th European LS-DYNA Conference – 15. - 17.6.2015.

USAGE OF LS-DYNA IN METAL FORMING.

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DR. I. HEINLE, A. ICKES, T. SENNER

BMW GROUP

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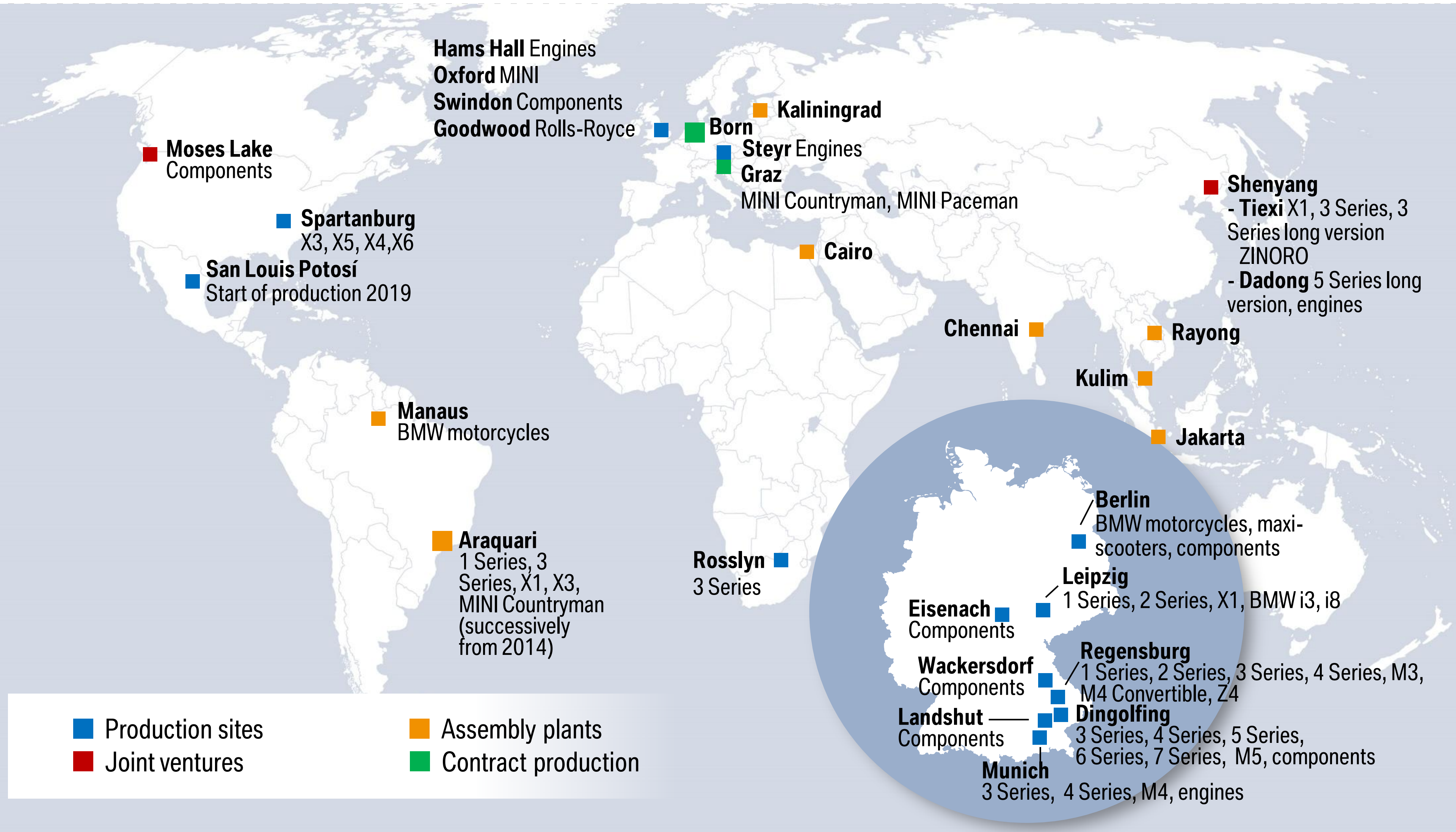
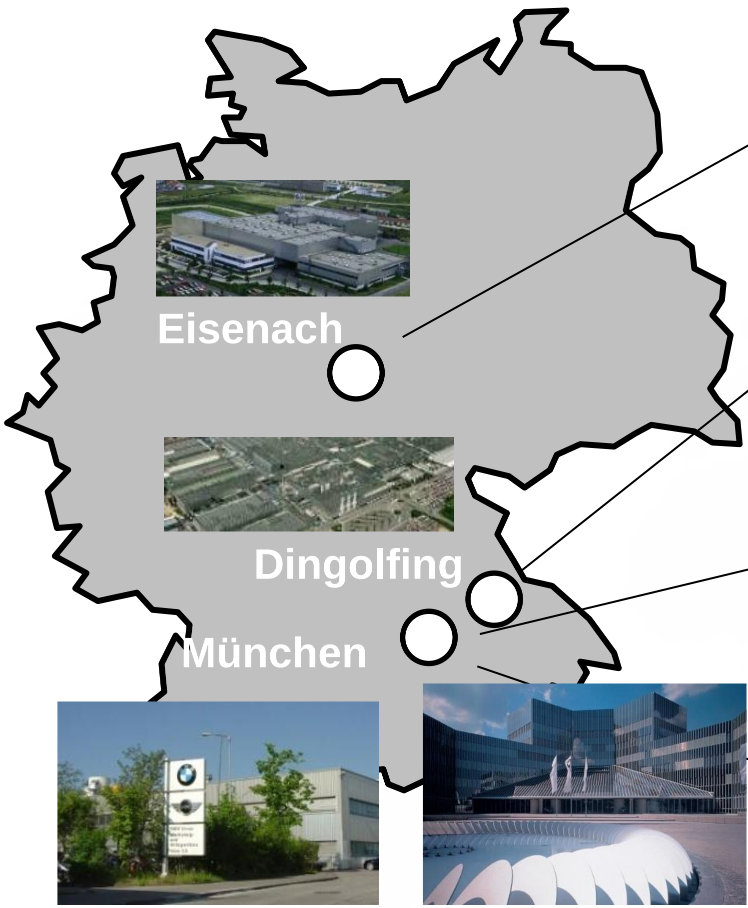
BMW GROUP PRODUCTION NETWORK.



INTRODUCTION.
TOOL SHOPS OF THE BMW GROUP.



Eisenach – Tool shop:
Process design.
Tool Construction.
Tool Production.

Dingolfing - Tool shop:
Process design.
Tool Construction.
Tool Production.
Support for Production.

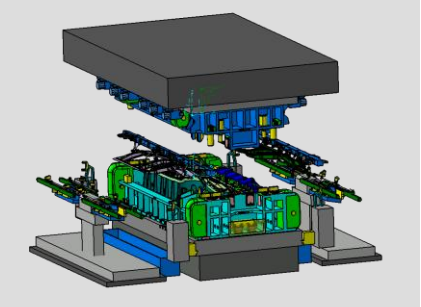
Munich – Tool shop:
Tool Construction.
Tool Production.
Support for Production.

Munich - FIZ-Network:
Concept of Production.
Tool Development.
Tool Construction.
Process validation.

INTRODUCTION.
FROM DESIGN TO TOOL AND PRESS.

– Car design.

– Process layout.

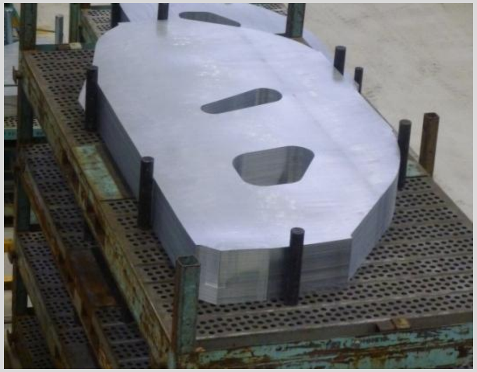


– Production of parts.

INTRODUCTION.
PRESS SHOP.

– Raw material.

– Coil-cut.

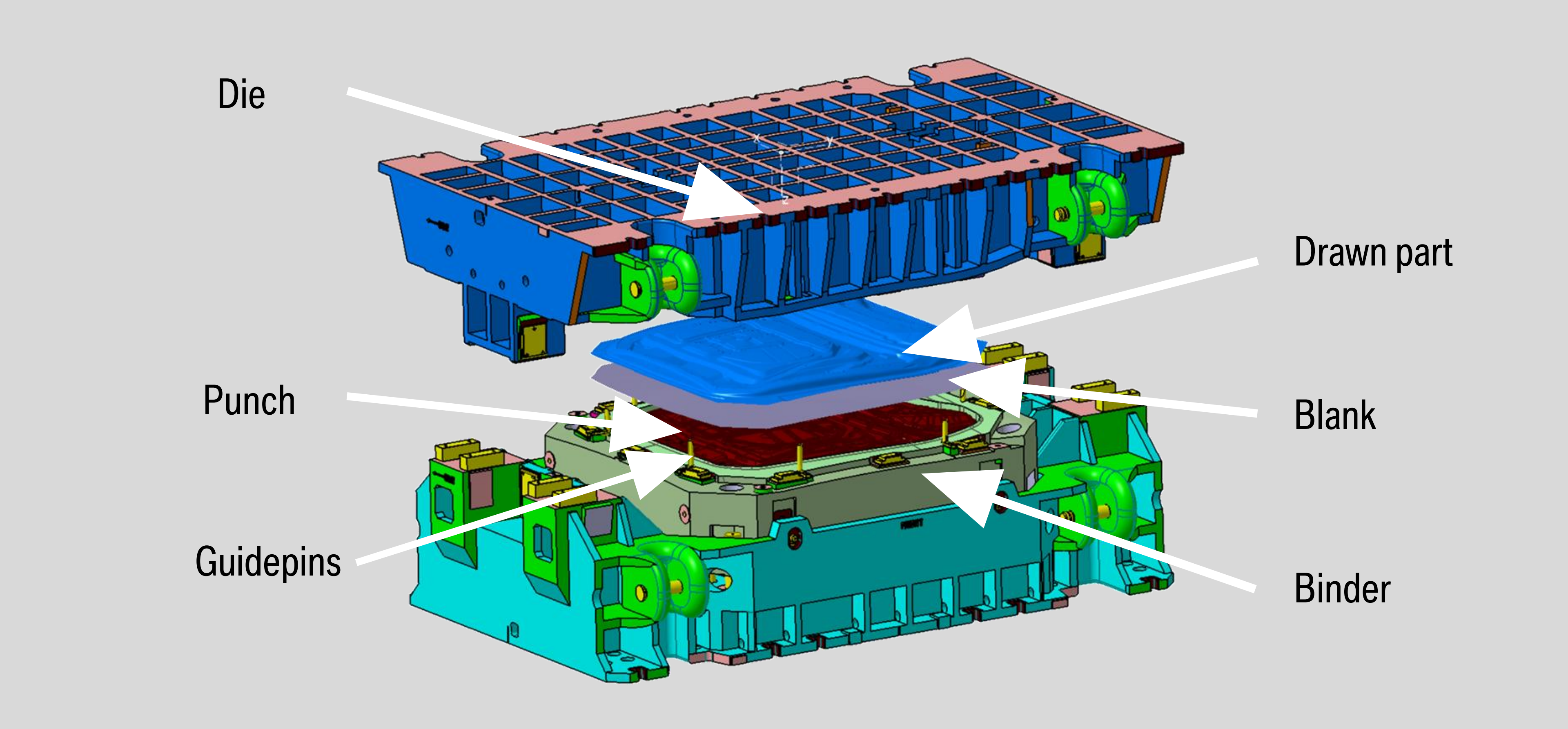


– Press line.

– Forming tool.

INTRODUCTION. PRESS SHOP.

Exemplary setup of a forming tool of a hood-inner.



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– Introduction.

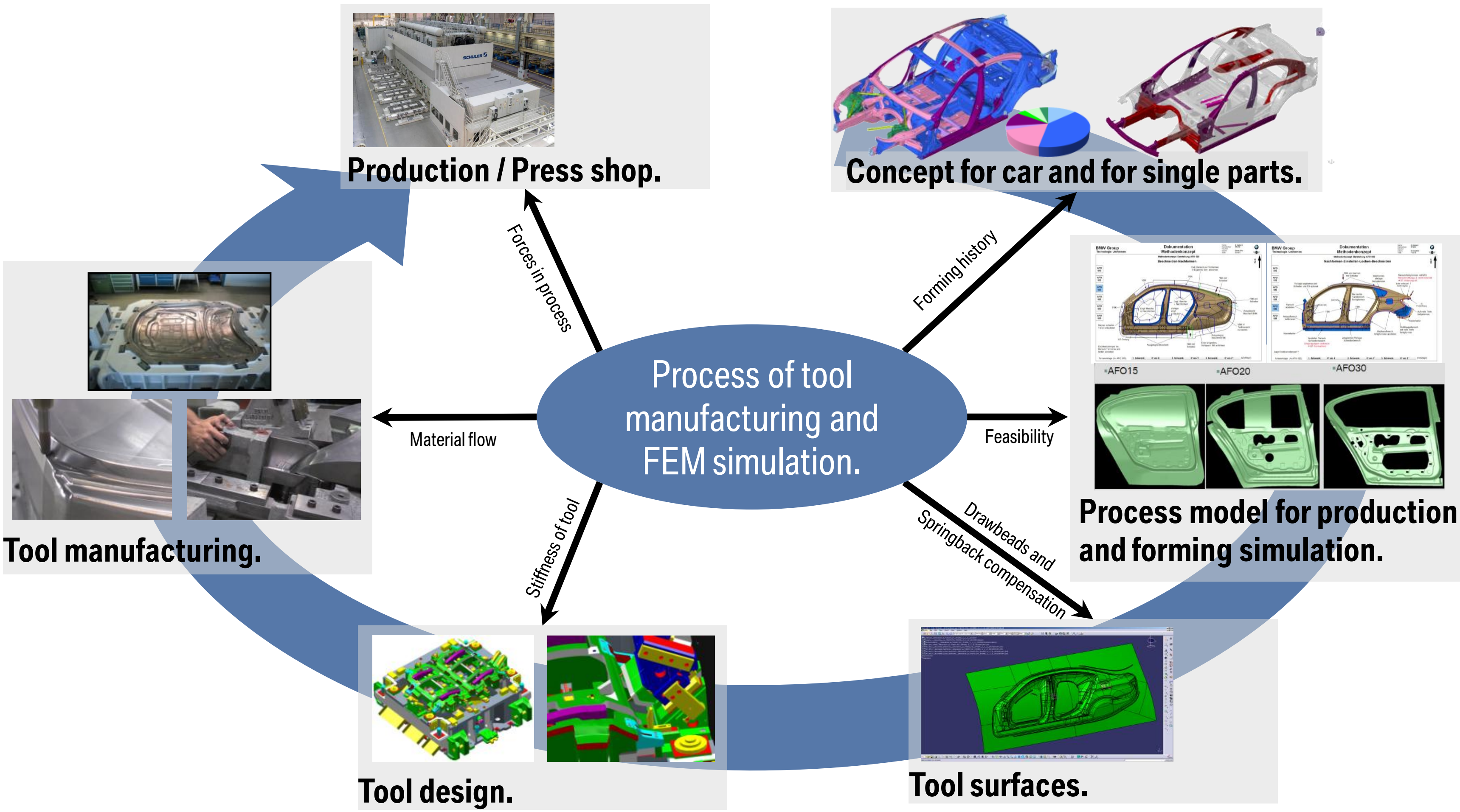
– Forming simulation at BMW – State of the art.

– Limiting factors for the current simulation systems.

– Summary of current use of LS-DYNA.

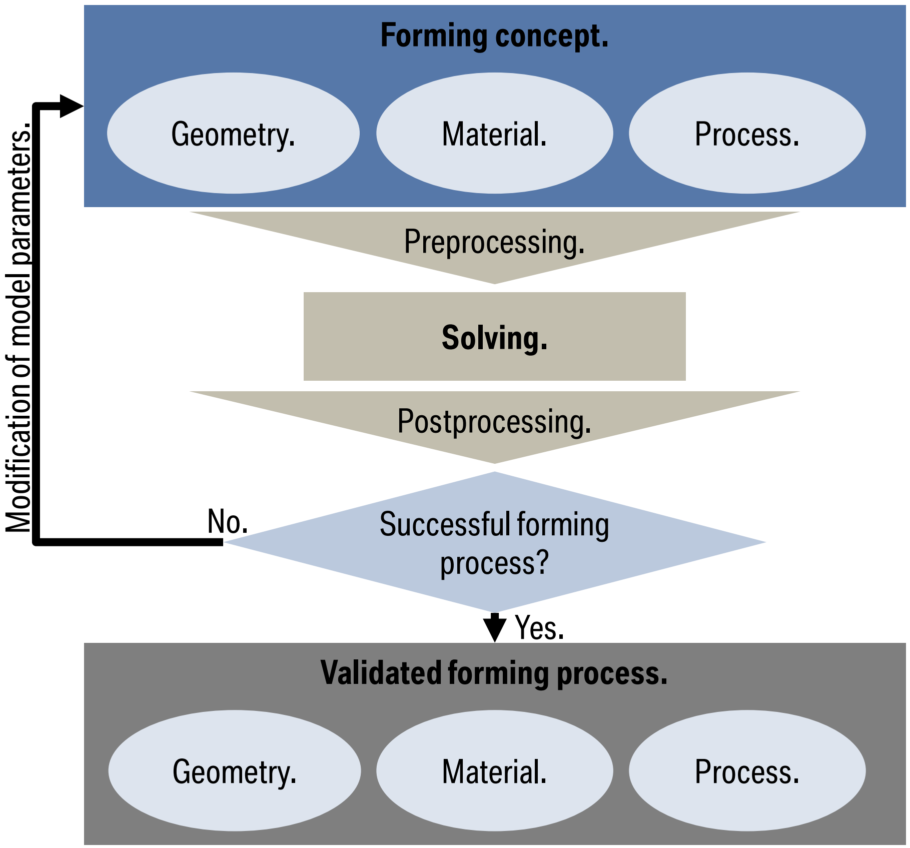
– Future challenges.

FORMING SIMULATION AT BMW – STATE OF THE ART. APPLICATION OF SIMULATION IN THE TOOL DEVELOPMENT PROCESS.

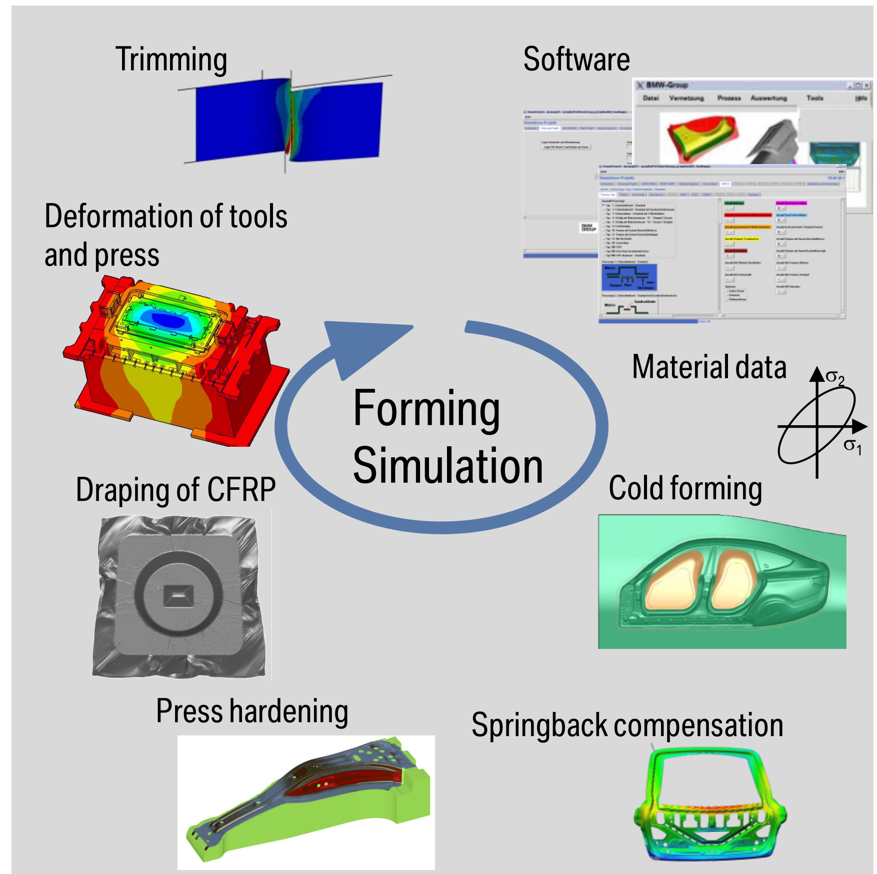


FORMING SIMULATION AT BMW – STATE OF THE ART. SOFTWARE CONCEPT.

– Modular setup of the processes.



– Application of forming simulation.

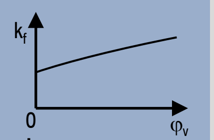


FORMING SIMULATION AT BMW – STATE OF THE ART. DETERMINATION OF MATERIAL PARAMETERS.

Generation of material cards: Selection of the used material model and definition of the model parameters.

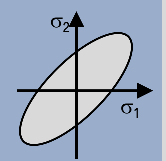
Fundamental experiments.

- Tensile test.
- Bulge test.
- Miyauchi test.
- Strip drawing test.



Selection constitutive laws.

- Elasticity.
- Plasticity.
  - Yield locus.
    (Hill, Barlat, Dell,…)
  - Hardening.
    (Kinematic hardening, Strain rate sensitivity, …)

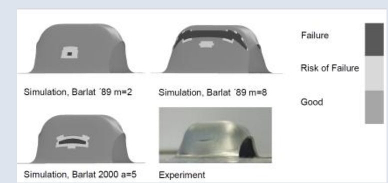


Determination of model parameters.

- Measured
  - strain states.
  - strain rate ratios.
  - stress states.

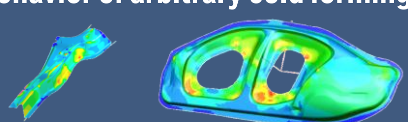
Validation of constitutive laws.

- Validation experiments.
- Comparison between the.



Generation of material cards.

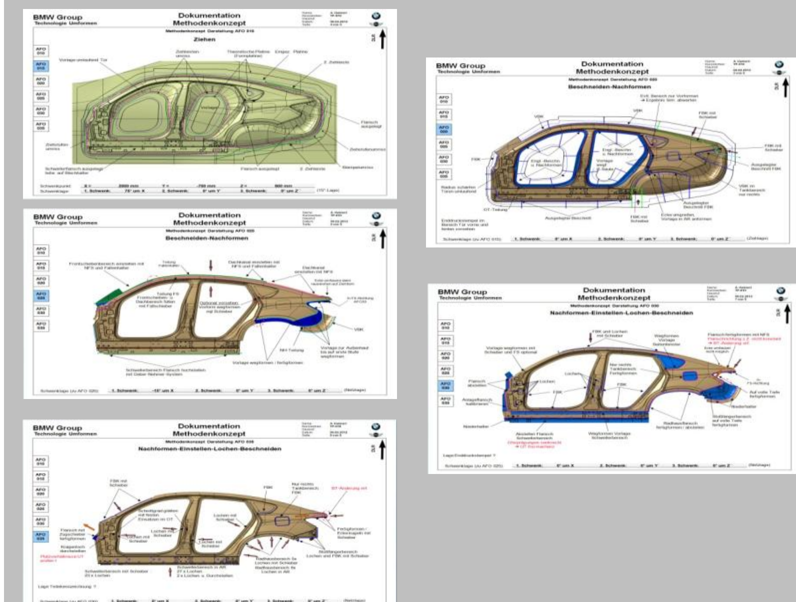
Prediction of the material response and the frictional behavior of arbitrary cold forming processes.



FORMING SIMULATION AT BMW – STATE OF THE ART. COLD FORMING.

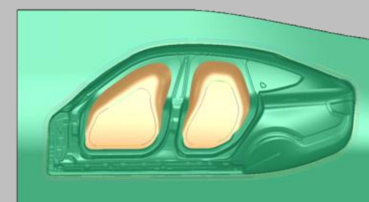
Design of production and cold forming simulation.

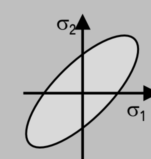
2D process plan.

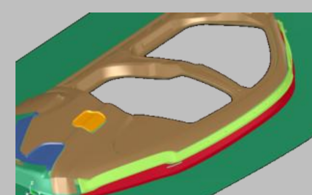


Simulation model.

OP1 - Drawing







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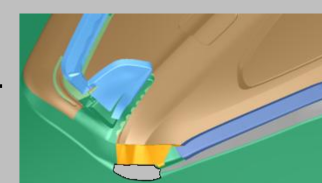
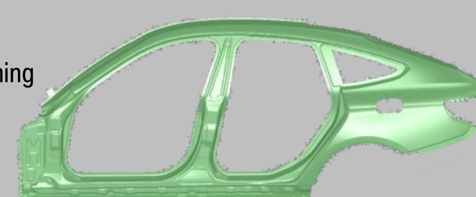
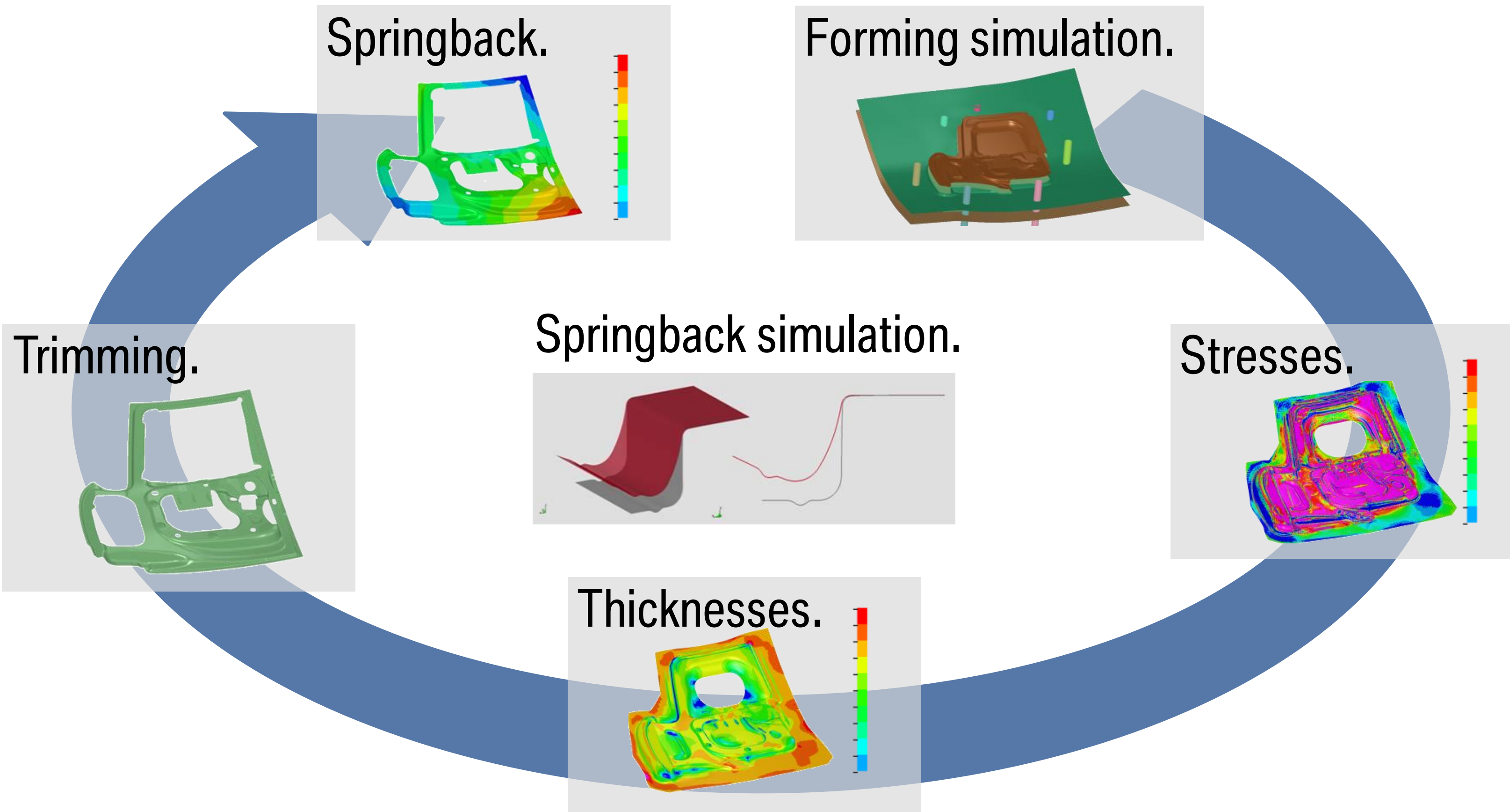


OP5 – Final forming



FORMING SIMULATION AT BMW – STATE OF THE ART. SPRINGBACK COMPENSATION.

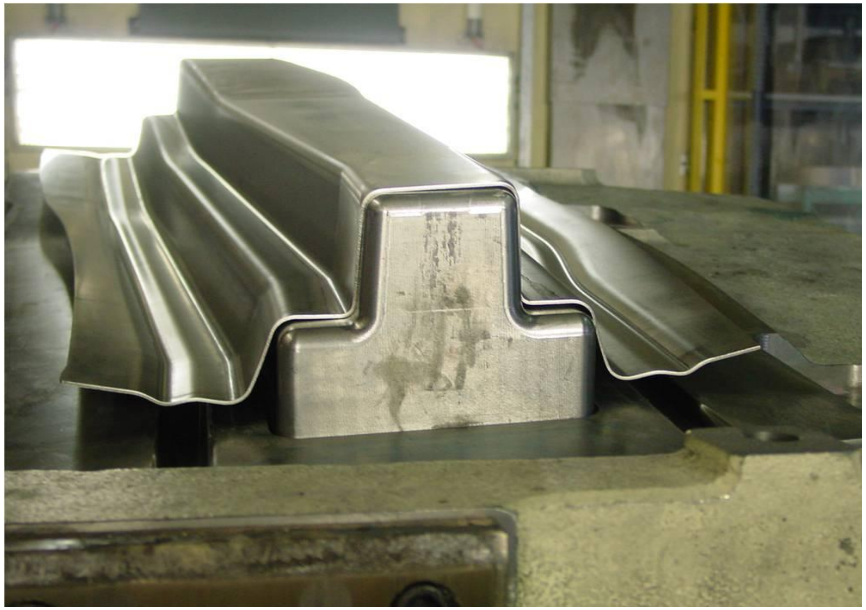
From forming simulation to springback.



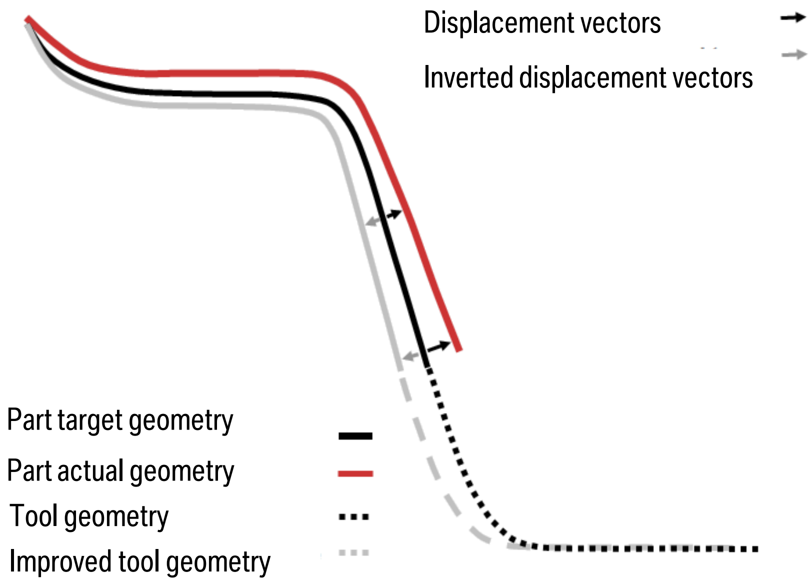
FORMING SIMULATION AT BMW – STATE OF THE ART. SPRINGBACK COMPENSATION.

Tool surfaces are modified within the springback compensation process based on simulated or measured data.

– Elastic springback.



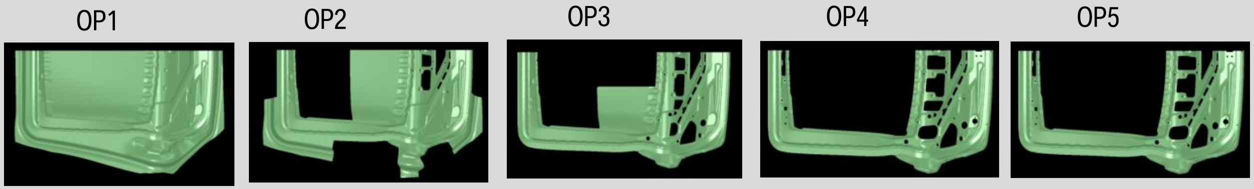
– Basic concept of springback compensation.



FORMING SIMULATION AT BMW – STATE OF THE ART.
SPRINGBACK COMPENSATION.

Example: 3 Series Gran Turismo - trunk lid inner- prototype.

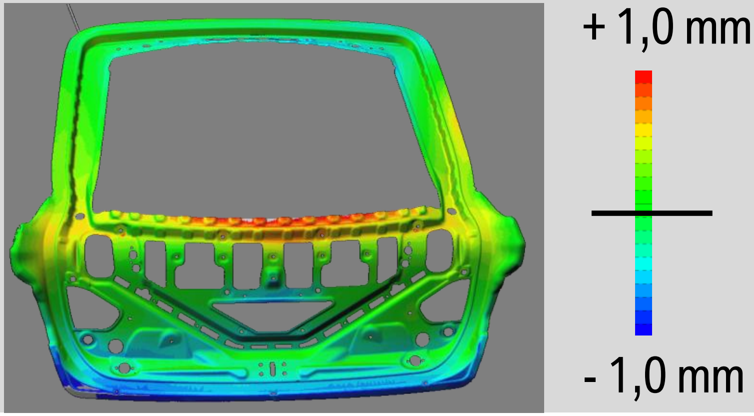
– Numerical representation of the production process.



– Springback compensation of the tool surfaces.

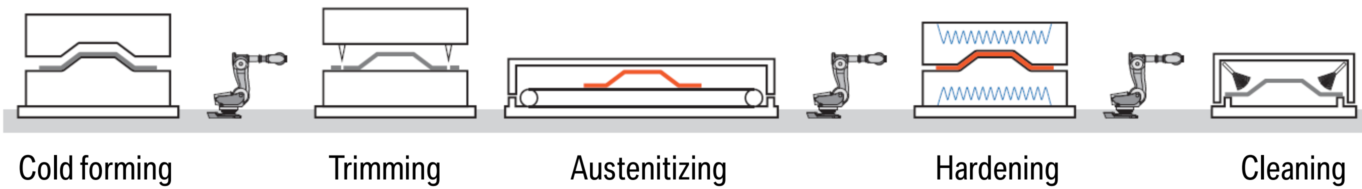
– Springback result of the final physical part.

➔ Measured data vs. simulated data.



FORMING SIMULATION AT BMW – STATE OF THE ART. INDIRECT PRESS HARDENING.

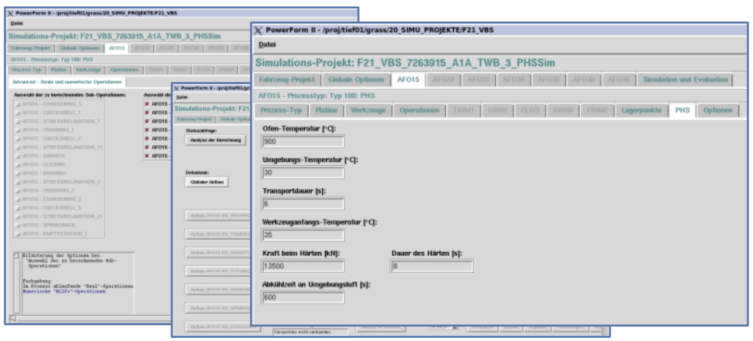
Process consisting of multi stage cold forming followed by heat treatment of the trimmed cold formed part.



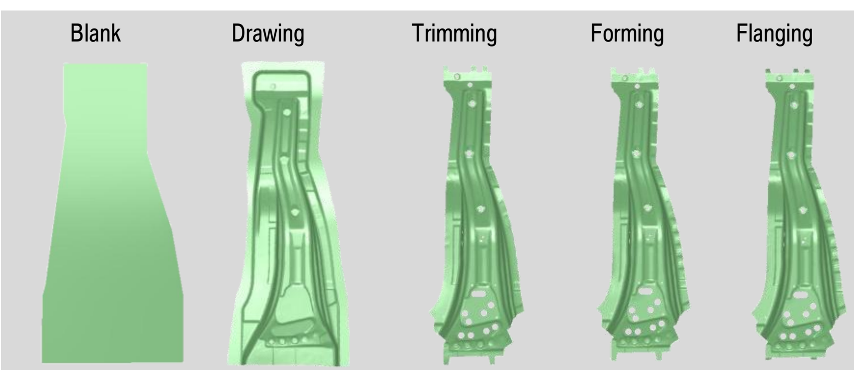
- Objectives:
  - Tailoring the strength of the part.
  - Geometrically accurate parts made from press hardened steel with complex geometry.

FORMING SIMULATION AT BMW – STATE OF THE ART. INDIRECT PRESS HARDENING.

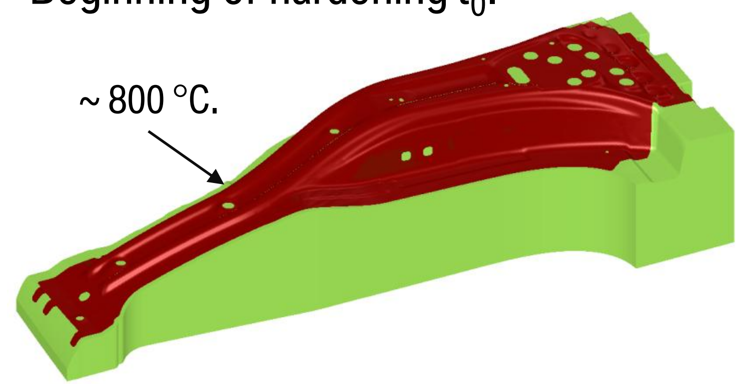
- Automated generation of the press hardening process model for simulation using in-house software tools.



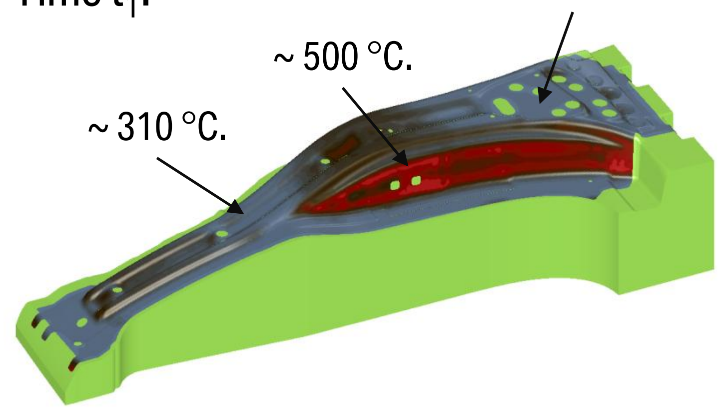
- Cold forming of b-pillar reinforcement.



- Press hardening of b-pillar reinforcement.
  - Beginning of hardening t_0.



  - Time t_1.

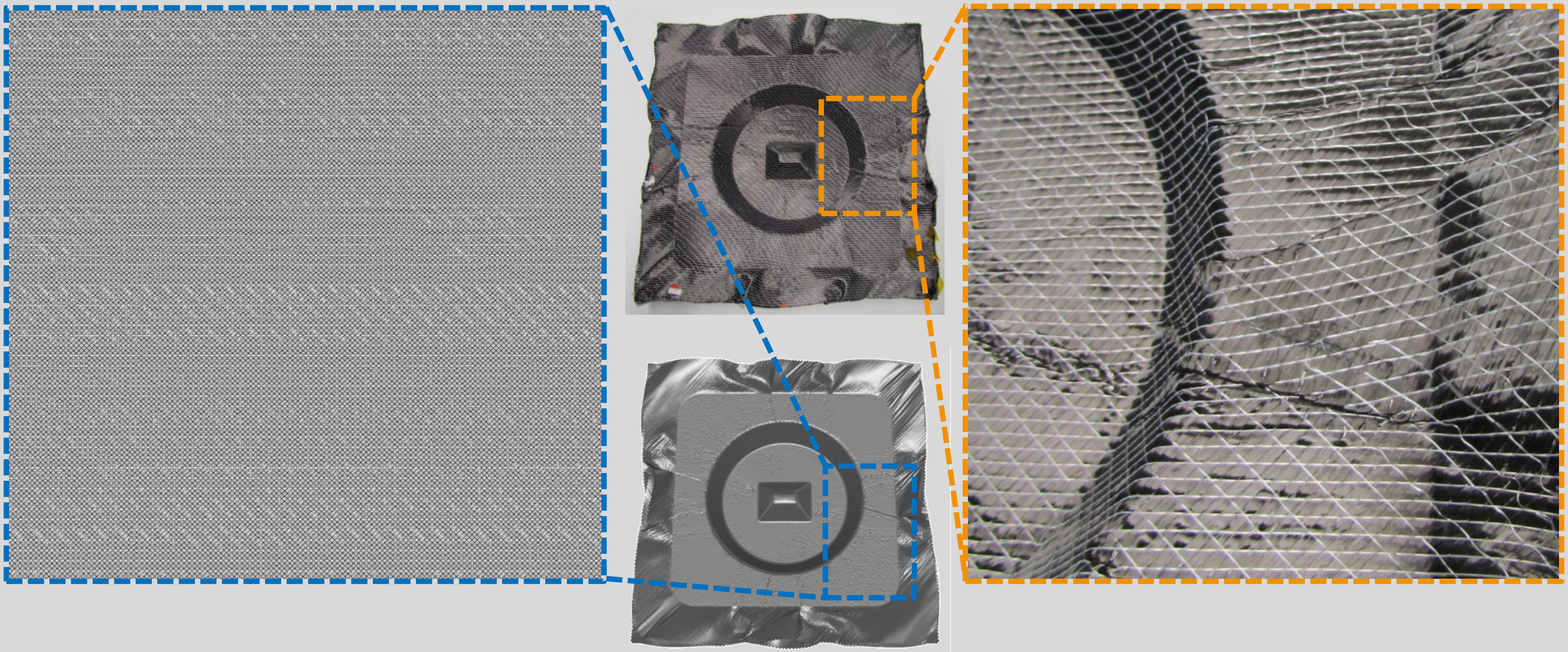


FORMING SIMULATION AT BMW – STATE OF THE ART. DRAPING OF CARBON FIBER REINFORCED PLASTICS.

Challenging example geometry.

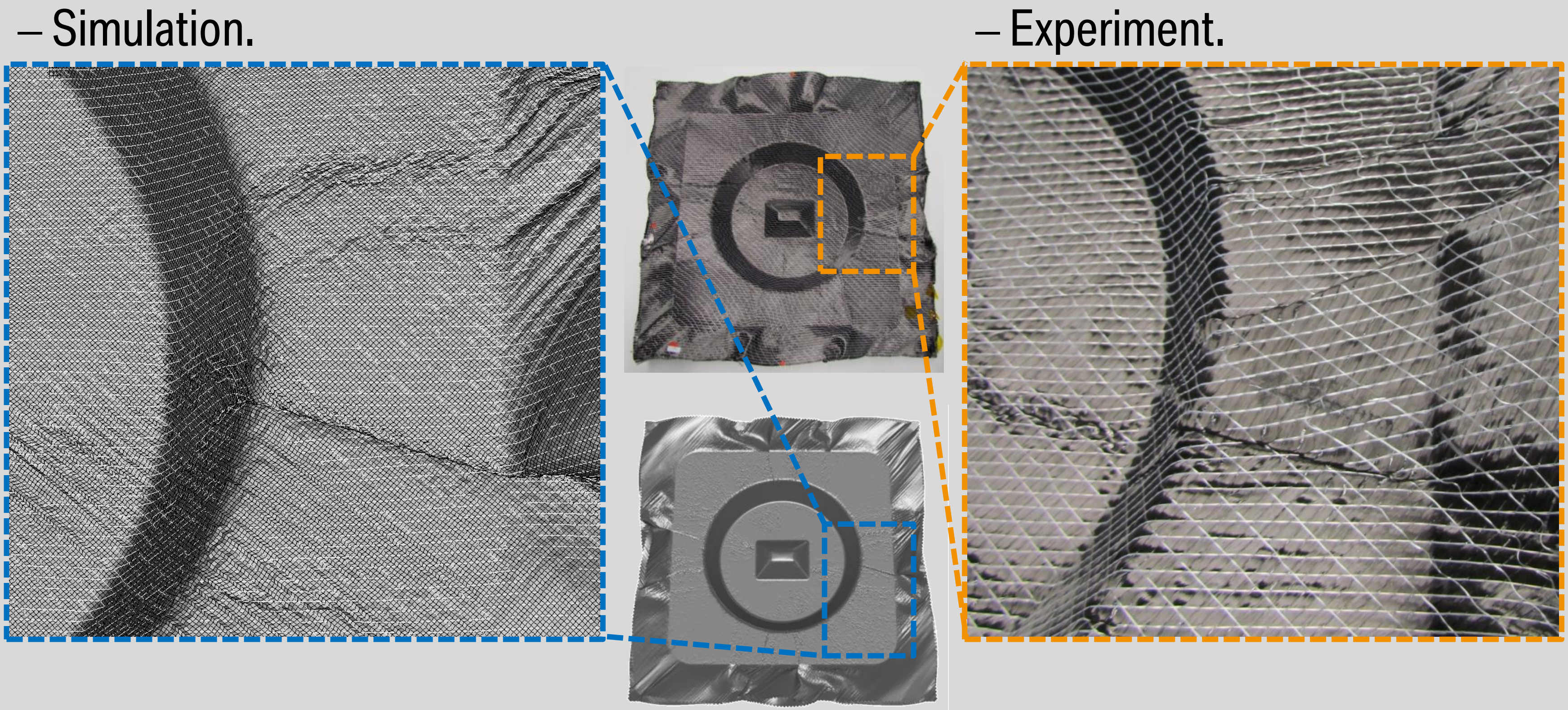
– Simulation.

– Experiment.



FORMING SIMULATION AT BMW – STATE OF THE ART. DRAPING OF CARBON FIBER REINFORCED PLASTICS.

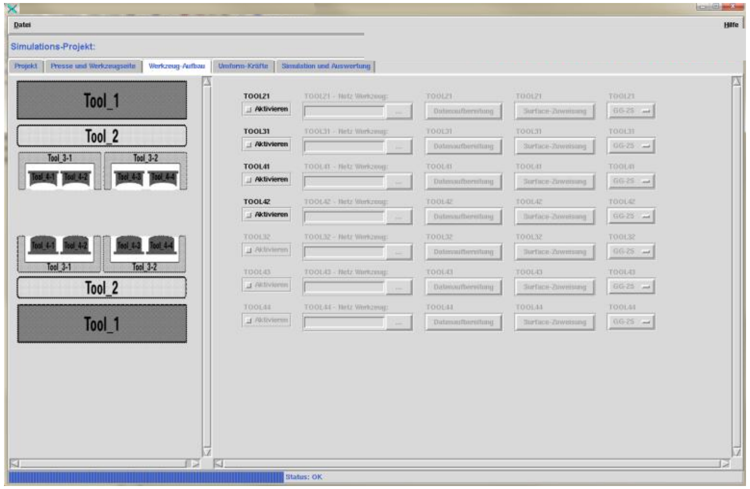
Challenging example geometry.

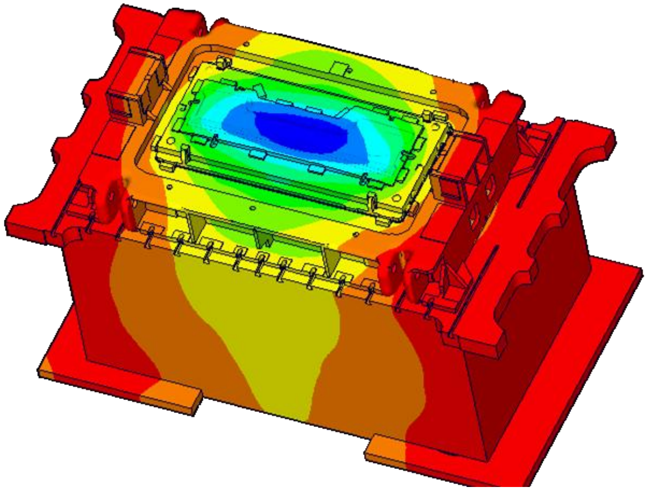


⇒ **Numerical prediction of wrinkles matches experimental results.**

FORMING SIMULATION AT BMW – STATE OF THE ART. DEFORMATION OF TOOL AND PRESS.

Simulation enables compensation and optimizations of the tool surfaces.



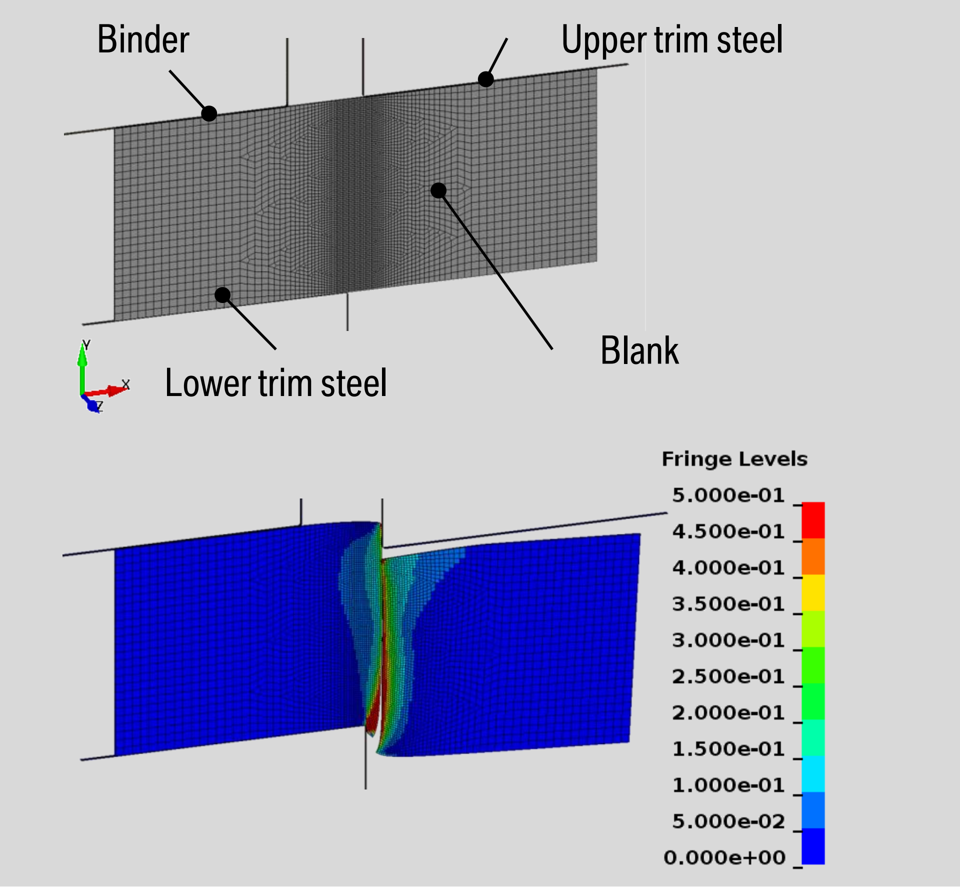


- Process modeling.
  - Tools (solids), drawn part from forming simulation, etc.
  - Process setup with BMW in-house software system.

FORMING SIMULATION AT BMW – STATE OF THE ART. TRIMMING OF THIN SHEET METAL.

- Objectives:
  - Strength and stiffness optimization of the trim steels.
  - Prediction of edge fracture during restriking.

- Modeling:
  - Employing enhanced material cards and fracture models.
  - Employing volume elements (plain stress would be an invalid assumption).



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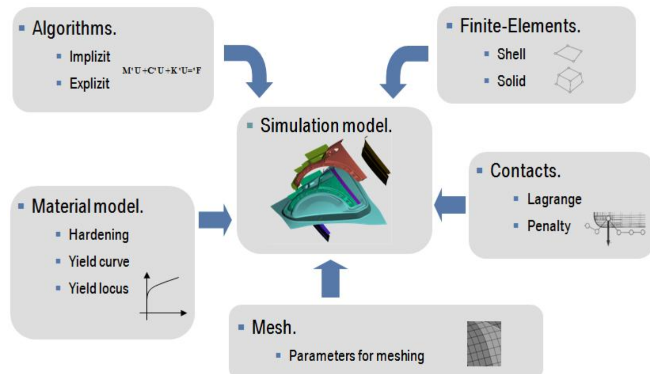
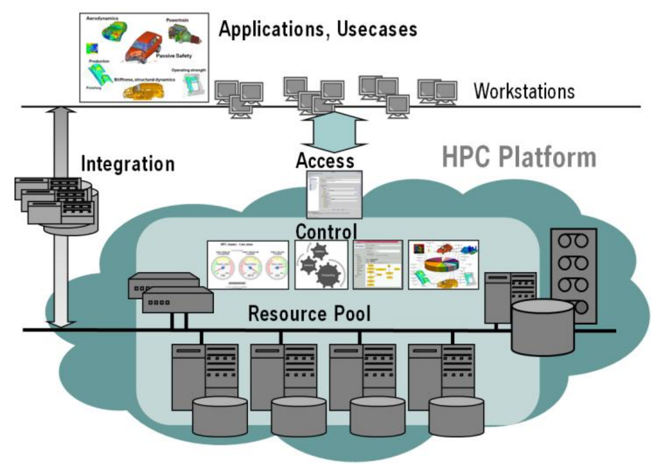
LIMITING FACTORS FOR THE CURRENT SIMULATION SYSTEMS.
SOLVER AND INFRASTRUCTURE.

- Limits of solver and numerical modeling.
  - Number of degrees of freedom.
  - Element formulation.
  - Kinematic of press and tool systems.



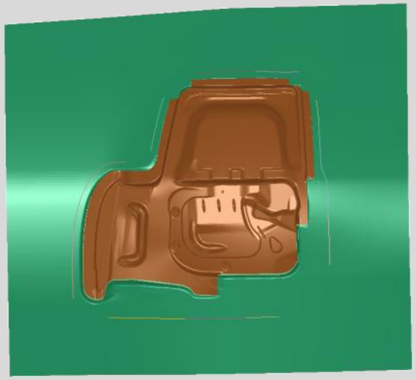
- Limits of computer-hardware.
  - CPUs.
    - Cores / Clock frequency ➔Cost.
    - 32- vs. 64-Bit – Single- vs. DoublePrecision.
  - Main Memory - RAM.
  - Connectivity between the cluster nodes.



LIMITING FACTORS FOR THE CURRENT SIMULATION SYSTEMS. EXAMPLES FROM ENGINEERING PROCESS.

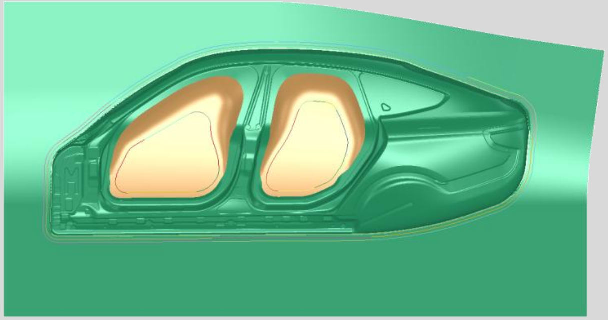
Simulation of large models – daily engineering.

- Mini Clubman – Door Inner: Simulation with line beads (Initial design).



–Number of elements: ~ 600.000
–Element size: 1,2 mm
–Computational time: 32CPUs: ~ 1,1 h

- 3 Series Gran Turismo – Side frame: Simulation with line beads (Initial design).

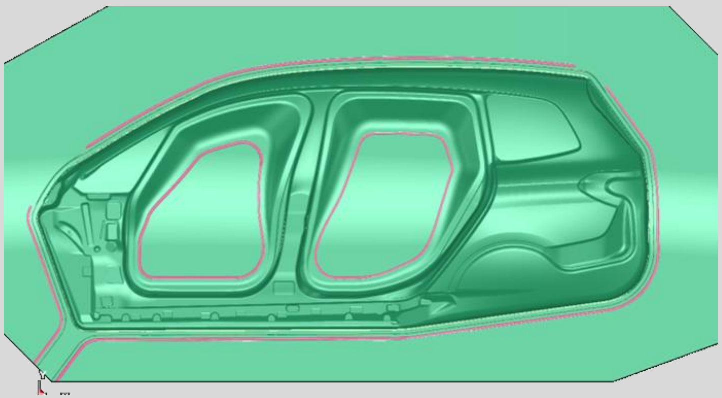


–Number of elements: ~ 2.400.000
–Element size: 1,4 mm
–Computational time: 32CPUs: ~ 6,8 h

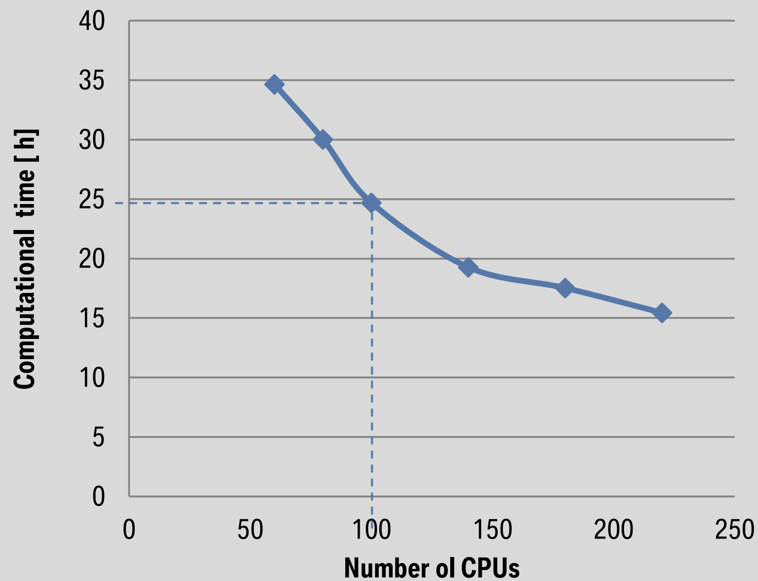
LIMITING FACTORS FOR THE CURRENT SIMULATION SYSTEMS.
EXAMPLES FROM ENGINEERING PROCESS.

Simulation of large models – daily engineering.

– 2 Series Gran Tourer –Side frame: Simulation with geom. drawbeads (Validation).



–Number of elements: ~ 7.500.000
–Element size: 0,7 mm
–Computational time: 100 CPUs: ~ 24 h



⇒ **Simulation results for large forming models in the daily engineering process are available within 24h.**

⇒ **Software / Solver should continuously be optimized for available hardware.**

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SUMMARY OF CURRENT USE OF LS-DYNA.

– Usage of LS-DYNA solver in cold forming and springback compensation in the daily tool-engineering is state of the art at BMW.

– Additional production processes are considered in the simulation models and these models are optimized continuously.
  – Simulation of indirect press hardening.
  – Draping of carbon fiber reinforced plastics.
  – Trimming simulation.
  – Etc.

– Limits of the simulation systems are permanently analyzed and if necessary, the simulation systems' capabilities are enhanced.

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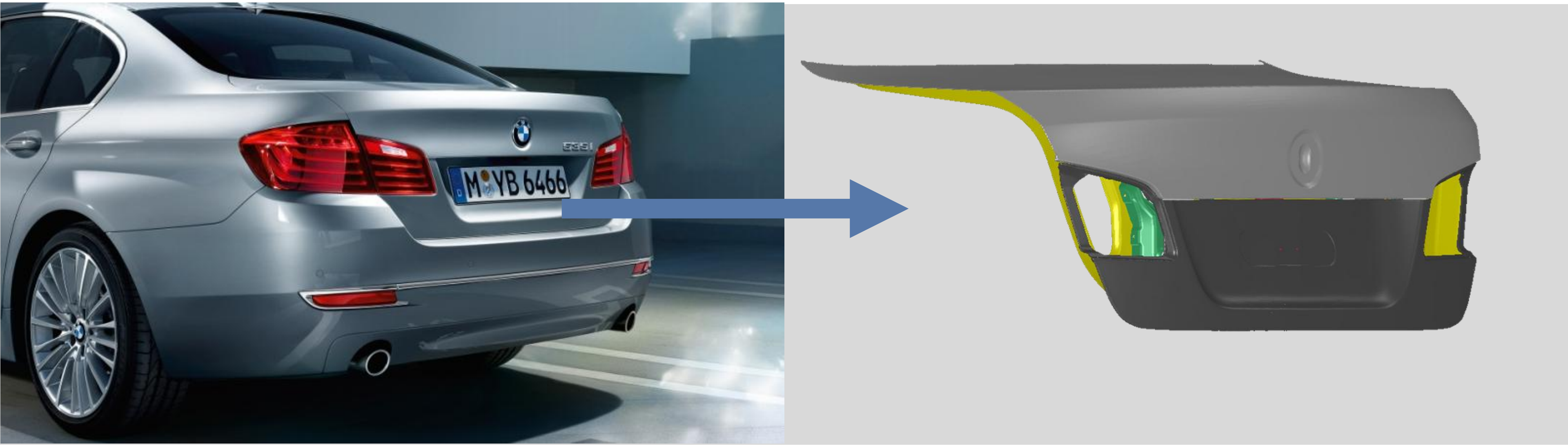
FUTURE CHALLENGES. PRODUCTION REQUIREMENTS.

- In the further production process, single parts are joined to the car body.
- The state of strain and stress of single parts is influenced by the joining operations which affects the springback of the entire assembly.
  - Simulating the assembly operation is important for the prediction of the final geometry of the assembly.

FUTURE CHALLENGES.
SIMULATION OF ASSEMBLIES.

Example of an assembly simulation - 5 Series Sedan trunk lid.

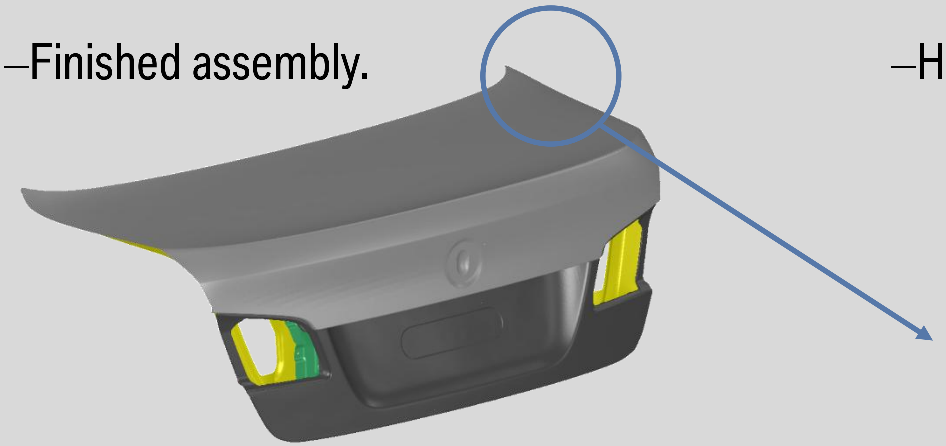
- Insertion of single parts.
- Modeling of spotwelds, weldlines and adhesives.
- Hemming simulation of the outer parts.



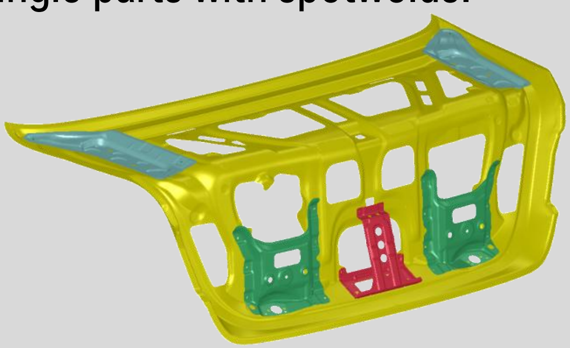
FUTURE CHALLENGES.
SIMULATION OF ASSEMBLIES.

Example of an assembly simulation - 5 Series Sedan trunk lid.

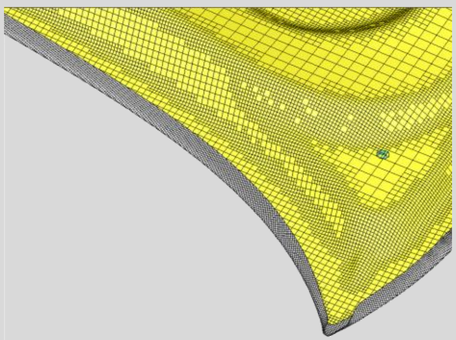
– Finished assembly.

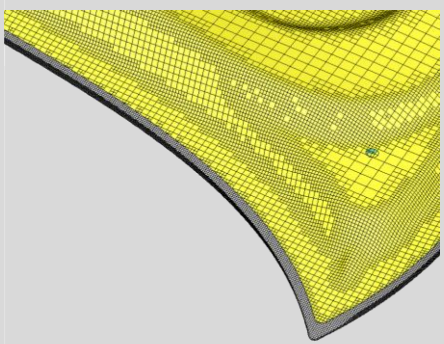


– Single parts with spotwelds.



– Hemming simulation at the labeled detail.

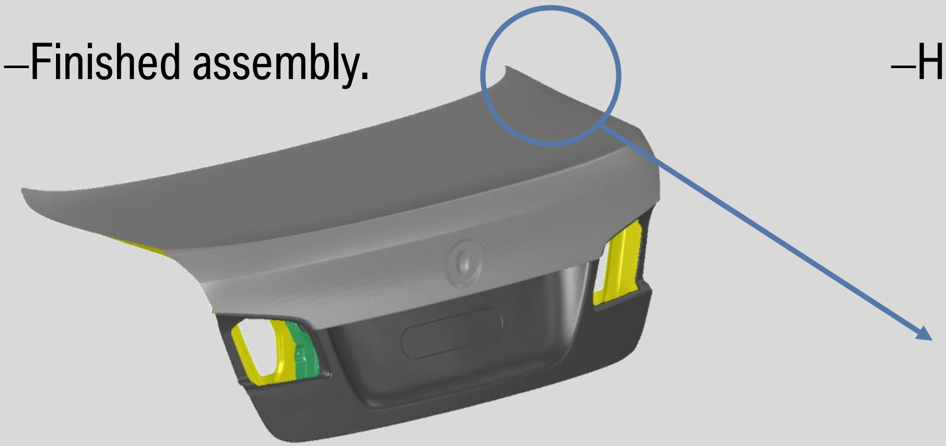




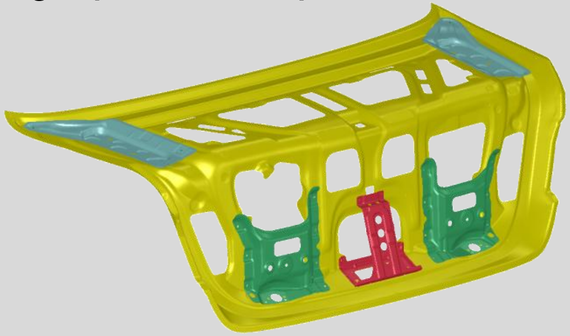
FUTURE CHALLENGES.
SIMULATION OF ASSEMBLIES.

Example of an assembly simulation - 5 Series Sedan trunk lid.

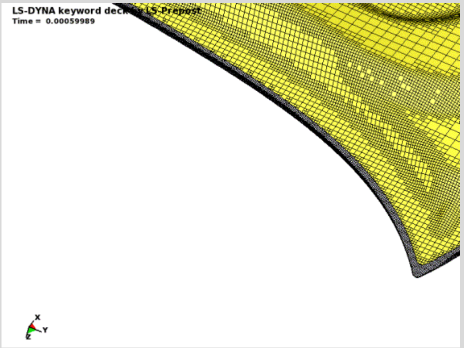
– Finished assembly.

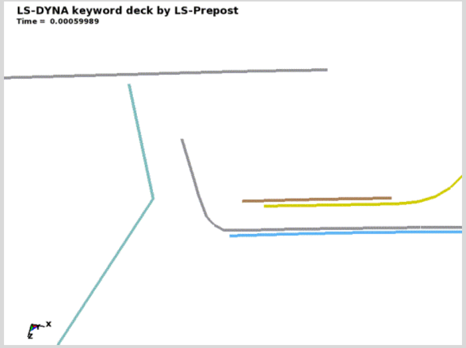


– Single parts with spotwelds.



– Hemming simulation at the labeled detail.

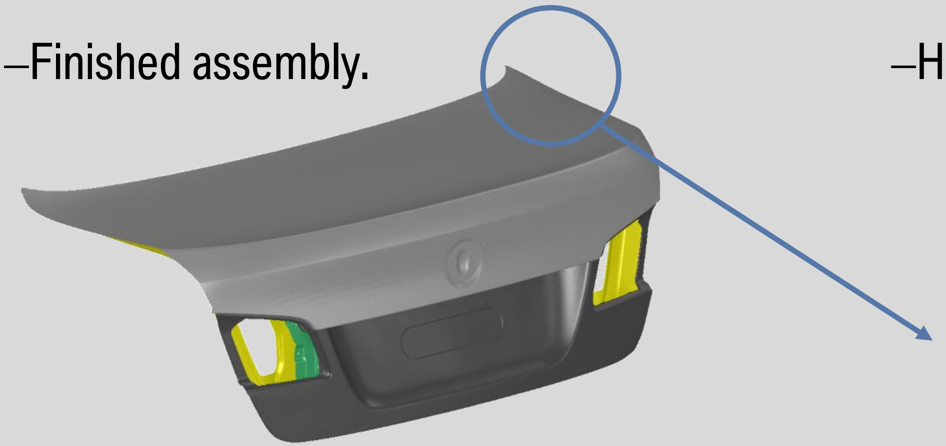




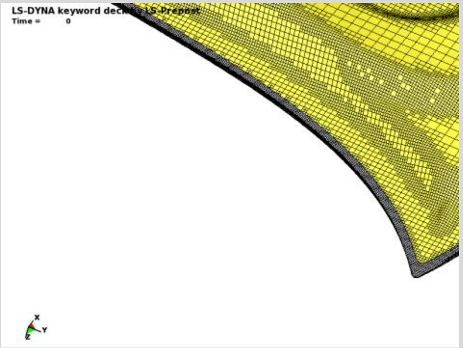
FUTURE CHALLENGES.
SIMULATION OF ASSEMBLIES.

Example of an assembly simulation - 5 Series Sedan trunk lid.

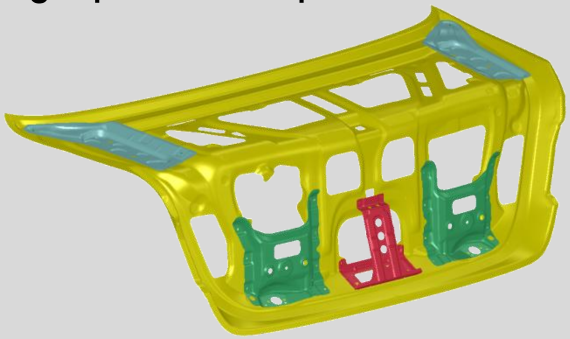
–Finished assembly.

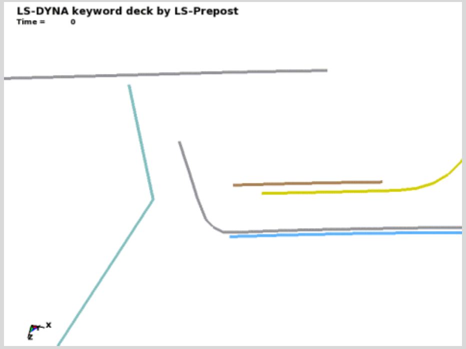


–Hemming simulation at the labeled detail.



–Single parts with spotwelds.



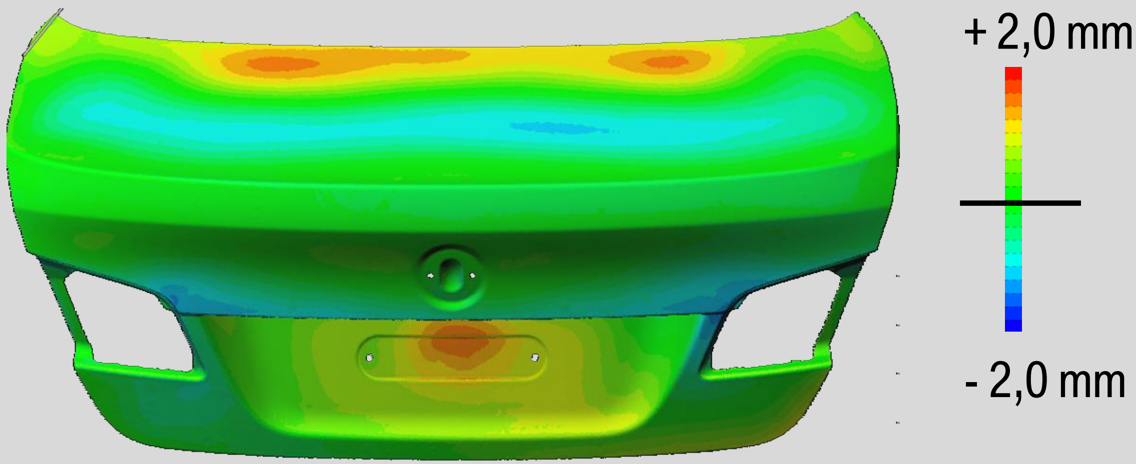


FUTURE CHALLENGES. SIMULATION OF ASSEMBLIES.

Example of an assembly simulation - 5 Series Sedan trunk lid.

– Springback simulation of prototype assembly.

  – Diagram: Deviation of simulation and target-geometry.



⇒ Simulation results enable adjustments and optimization of the assembly process.

THANK YOU VERY MUCH FOR YOUR ATTENTION.