
USAGE OF LS-DYNA IN METAL FORMING.

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INTRODUCTION.

BMW GROUP PRODUCTION NETWORK.

Production sites

- Spartanburg
- Manaus
- Moses Lake
- Johannesburg
- Kaliningrad
- Graz
- Cairo
- Chennai
- Rayong
- Jakarta
- Moscow
- Shenyang
- Berlin
- Leipzig
- Regensburg
- Dingolfing
- Munich
- Eisenach
- Landshut
- Wackersdorf
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- Regen
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.
Exemplary setup of a forming tool of a hood-inner.
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FORMING SIMULATION AT BMW – STATE OF THE ART.
APPLICATION OF SIMULATION IN THE TOOL DEVELOPMENT PROCESS.

Production / Press shop.
Concept for car and for single parts.

Process of tool manufacturing and FEM simulation.

Tool manufacturing.
Tool design.
Tool surfaces.

Material flow
Stiffness of tool
Forces in process
Foming history
Feasibility
Drawbeads and Springback compensation
Process model for production and forming simulation.
FORMING SIMULATION AT BMW – STATE OF THE ART. SOFTWARE CONCEPT.

– Modular setup of the processes.

- Forming concept:
  - Geometry
  - Material
  - Process

- Preprocessing

- Solving

- Postprocessing

- Successful forming process?

- Yes

- Validated forming process:
  - Geometry
  - Material
  - Process

– Application of forming simulation:

- Software

- Material data

- Cold forming

- Trimmed

- Draping of CFRP

- Deformation of tools and press

- Press hardening

- Springback compensation

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.
- Miyachi 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.

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

**Generation of material cards.**

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

Design of production and cold forming simulation.

2D process plan.

Simulation model.

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.
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.
- Press hardening of b-pillar reinforcement.
  - Beginning of hardening $t_0$. 
    ~ 800 °C.
- Cold forming of b-pillar reinforcement.
- Time $t_1$. 
  ~ 310 °C.
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.

– Simulation.

– Experiment.

⇒ Numerical prediction of wrinkles matches experimental results.
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 \(\rightarrow\) 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.
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.

– Finished assembly.

– Hemming simulation at the labeled detail.

– Single parts with spotwelds.

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

– Finished assembly.

– Single parts with spotwelds.

– Hemming simulation at the labeled detail.
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.

DER NEUE BMW 7er.