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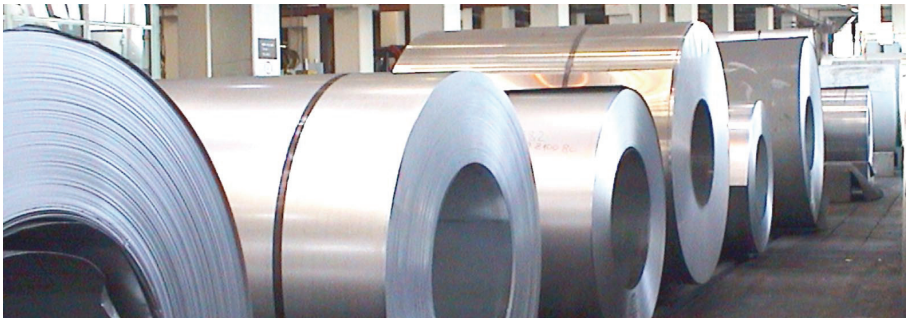
Status and Future Applications of Sheet Metal Forming Simulation.



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Status and future applications of sheet metal forming simulation.
Content.

Introduction

State-of-the-art in sheet metal forming simulation
- Process chain „Painted Body“
- Producibility Assessment
- Process optimization
- Springback
- Collision detection
- Transfer of forming results in functionality assessment

Future trends and potential for development
- Incorporation of high-strength materials
- Die compensation
- Press forces
- Follower operations and hemming
- Stress calculation
- Robust design/optimization
- Improved failure criteria

Conclusion

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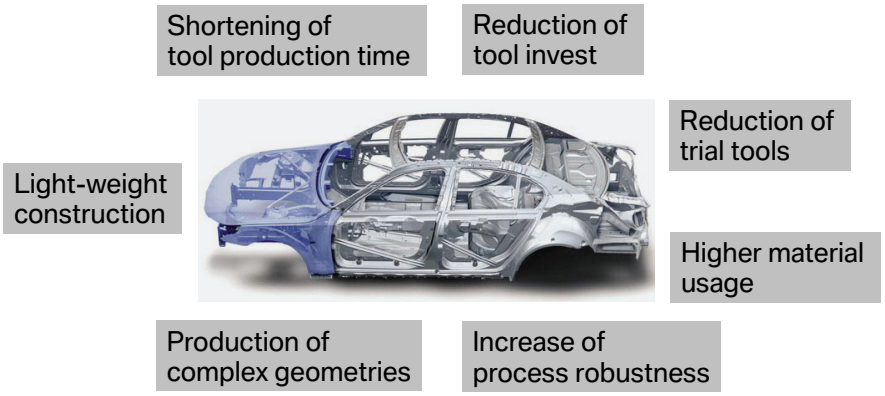
Status and future applications of sheet metal forming simulation.

Impact on time, costs and quality.



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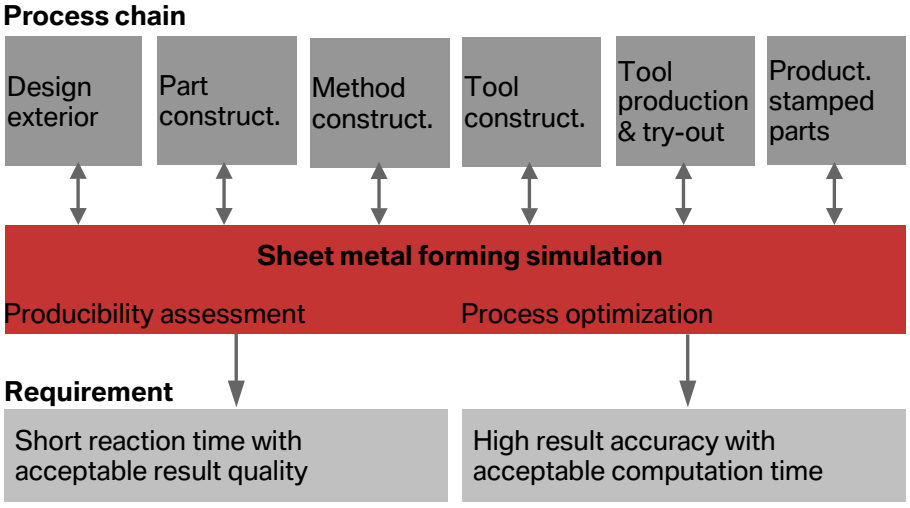
Status and future applications of sheet metal forming simulation.

Fields of application of stamping simulation.



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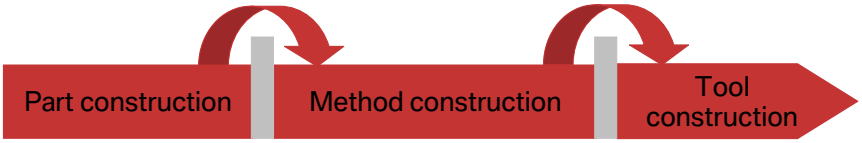
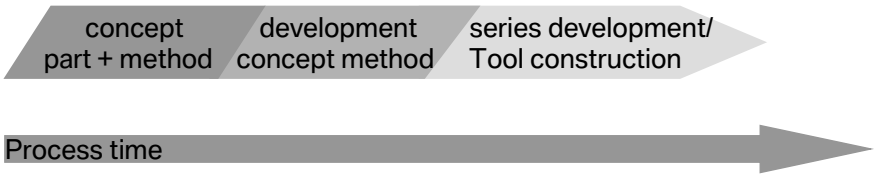
Status and future applications of sheet metal forming simulation.

Overlapping virtual development process.

Sequential virtual development process:



Overlapping parallel virtual development process:



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Status of sheet metal forming simulation.

A cost and time effective overlapping development of part geometry and production technique can be reached by

- A flexible, fast construction tool
- Parametric tool construction
- Fast and exact produciblity assessment of concepts by simulation
- Process optimization during series development

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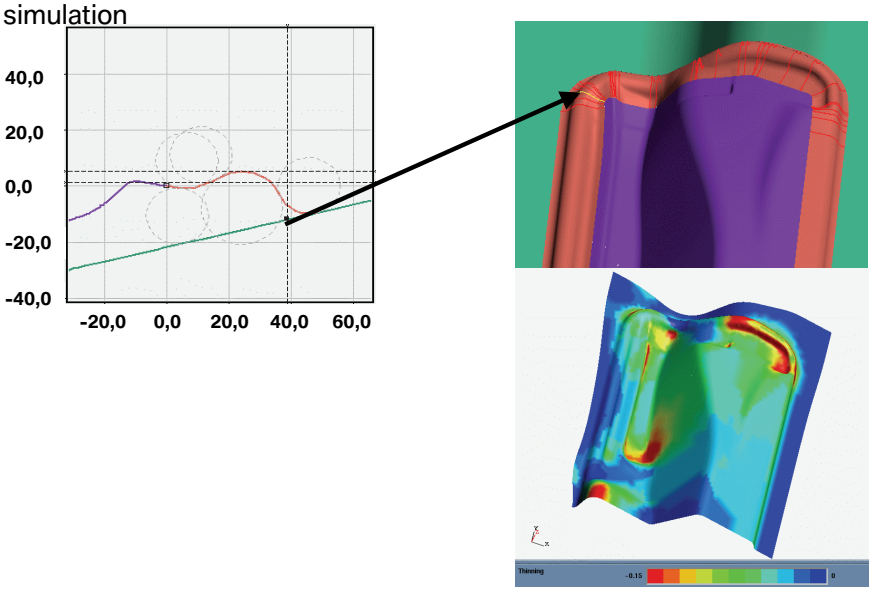
Produciblity assessment.

Parametric die design and produciblity assessment by implicit incremental simulation



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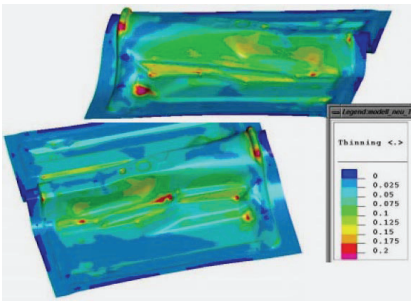
Status of sheet metal forming simulation.
Process optimization.

In the later design stage failure of a die design is assessed.



The following criteria have to be fulfilled:

Functionality:

– Stability (cracks, wrinkles or overlaps)

– Dimensional accuracy (springback)

– Stiffness (excessive thinning)

Optical appearance:

– Waviness, surface disturbance

– Slip lines

Process optimization includes:

- Drawbead geometry
- Springback
- Press forces

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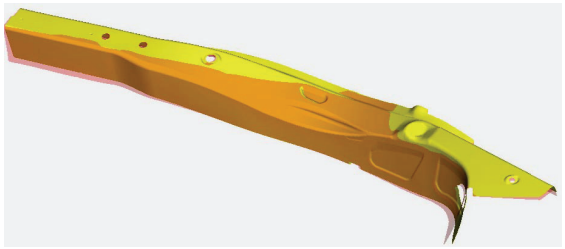
Status of sheet metal forming simulation.
Springback computation.

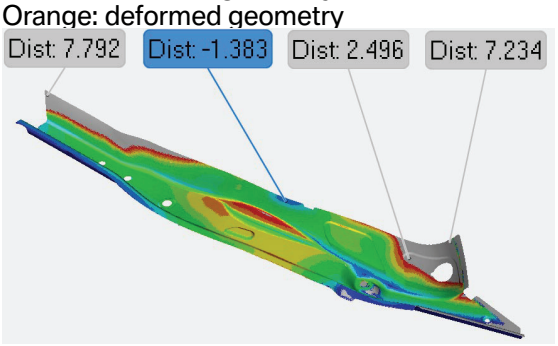
Elastic stresses in the deep drawn part cause springback after opening the die.

This causes unwanted changes of the geometry in the part.

The implicit springback calculation provides valuable information for the die design.



Yellow: intended geometry
Orange: deformed geometry



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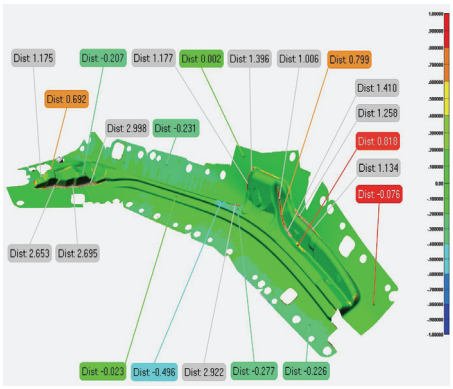
Status of sheet metal forming simulation.
Application of optical measurement.

The applications of optical measurement are:

- Archiving of tool geometry
- Re-engineering
- Comparison of simulation with reality
- Support in tool try-out
- Recommendations for improvement of process stability
- Monitoring of tool wear



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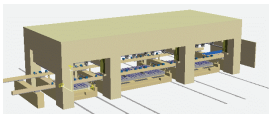
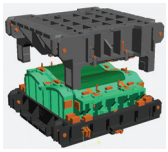
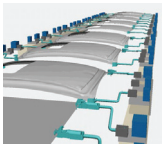
Status of sheet metal forming simulation.
Simulation of collision in press kinematics.



CAD press model

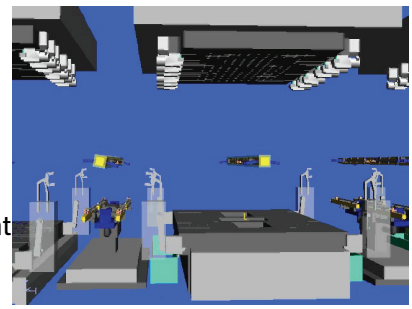


3D tool model



3D mechanisation

Virtual environment



Collision detection.

Simulation of all press and interior tool motions:
- Feeder kinematics
- tool change in press
- slider

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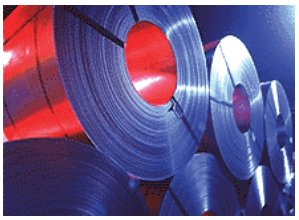
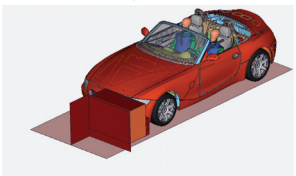
Status of sheet metal forming simulation.
Transfer of forming results in functionality assessment.

Incorporation of the production history in the functionality assessment of the car body, such as crash, stiffness, stability, strength.

Raw material → Forming process → Crash, stability, strength, stiffness





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Trends in sheet metal forming simulation.

Future trends and potential for development in sheet metal forming include the following:

- Incorporation of high-strength materials
- Die compensation
- Press forces
- Finite-Element Technology and material modelling
- Follower operations and hemming
- Modeling of complex 3D stress and strain states.
- Robust design/optimization
- Improved failure criteria

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Trends in der Umformsimulation von Al / Stahl.
Incorporation of high-strength materials.

To meet increased requirements in crash and stability the use of high-strength steels will go on increasing in the future.

This elevates the requirements in the virtual process chain regarding:

- Evaluation of press forces.
- Die compensation.
- Process design for follower operations.
- Cutting.
- Tool strength and stiffness.

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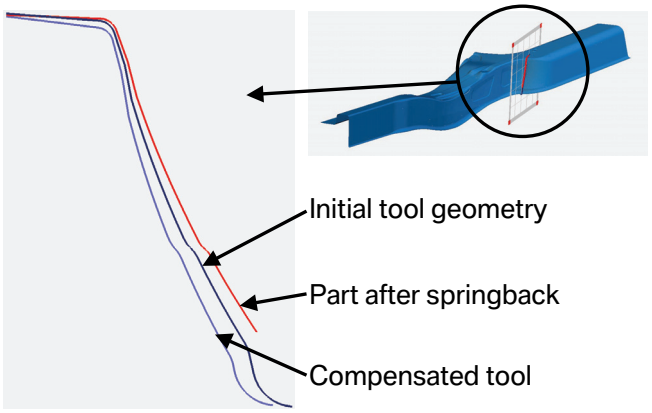
Trends in sheet metal forming simulation.
Die compensation.

Springback is traditionally compensated in the tool production.

To further reduce the production time of tools a compensation should be suggested in the die design stage.



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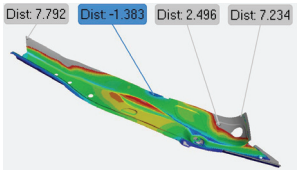
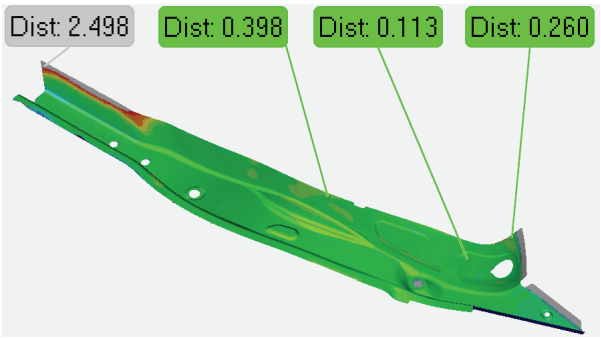
Trends in sheet metal forming simulation.
Die compensation.
Results.

Before compensation



After compensation



-2mm 2mm

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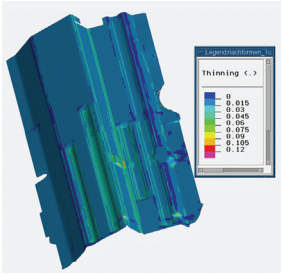
Trends in sheet metal forming simulation.
Prediction of press forces.

The choice of the correct production press is a determining factor for profitability.

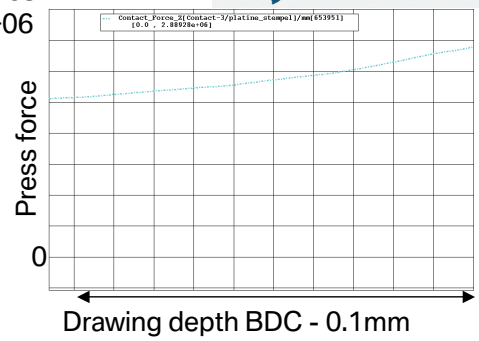
Prediction of the necessary press forces is thus essential.

Current simulation codes do not predict correct forces in all cases due to the contact algorithm



Typical press force characteristics:

Crash cross member
Thickness d=1.2mm,
Yield strength 935 N/mm²



Calculated Press force:
BDC - 0.10mm : F=210t
BDC - 0.06mm : F=230t
BDC - 0.03mm : F=255t
BDC : F=285t

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Trends in sheet metal forming simulation.
Finite Element Technology.

Several numerical approaches should be investgated for future use in sheet metal forming:

- Thickness stress and strain must be accounted for to compute an accurate stress distribution . This could be improved with:
  - Higher-order shell elements
  - *p*-adaptive finite-element method (pFEM)
  - Model adaptivity
  - Element-Free-Galerkin (EFG) method
- Material modelling to improve accuracy
  - Crystal plasticity
  - Improved hardening modells
  - Improved yield functions

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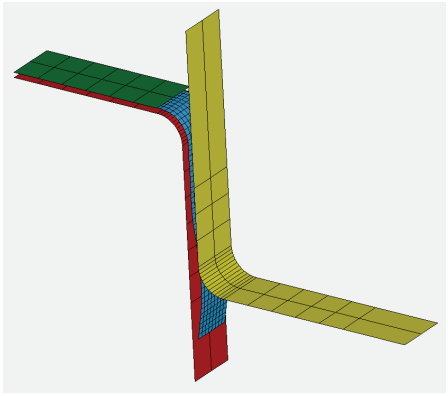
Trends in sheet metal forming simulation.
Modeling of follower operations and hemming.

Goals:
- Prediction of strains and stresses after follower operations and hemming
- Prediction of springback after follower operation and particularly after hemming
- Detection of surface defects
- Prediction of flange shortage in hemming



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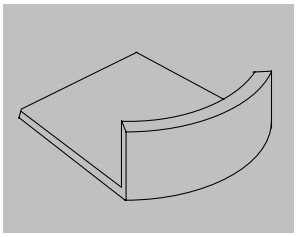
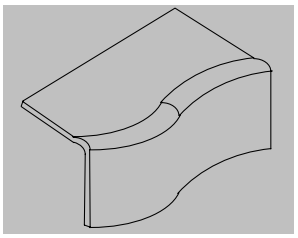
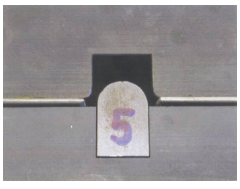
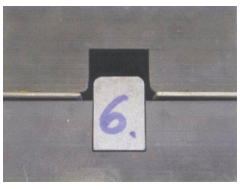
Trends in sheet metal forming simulation.
Modeling of complex 3D stress and strain states.

Modeling of complex sheet forming operations with the goal of accurate stress and strain prediction. Application examples:









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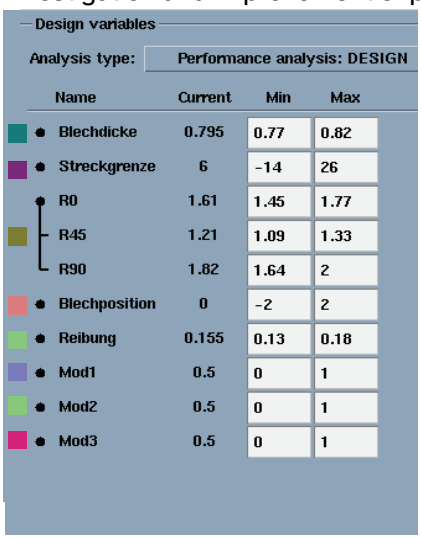
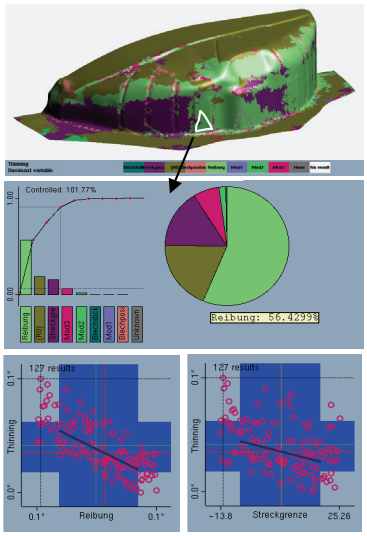
Trends in sheet metal forming simulation.
Robust design/optimization.

Sensitivity analysis

Investigation and improvement of process robustness





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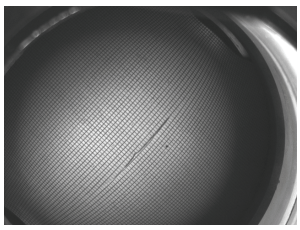
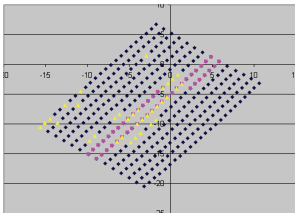
Trends in sheet metal forming simulation.
Numerical evaluation of the forming limit curve.

Algorithmic procedures for automatic evaluation and prediction of localized necking. Deformation states prescribed by optical mesh measurements.





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Status and future applications of sheet metal forming simulation.
Conclusion.

- Sheet metal forming simulation is nowadays an established tool in the design of a car body.
- Predictions of formability of the deep drawn part are sufficient for industrial use.
- To further exploit the impact of virtual methods the complete process chain must be incorporated.
- Efficiency and stability of software tools is a major industrial interest for complex applications (contact, large strains, millions of degrees of freedom) besides accuracy.

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Thank you for your attention.