Increasing Requirements on FE Simulations in the Automotive Industry

The Role of Mechanical Testing

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Zwick Roell

Content

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Target

Simulation has the general objective of increasing understanding and saving costs through the virtual prediction of system behavior.

Process understanding

Prediction of system behavior

Virtual laboratory for examinations that are too expensive, dangerous or time-consuming

Optimization of the tool development process in the early phase

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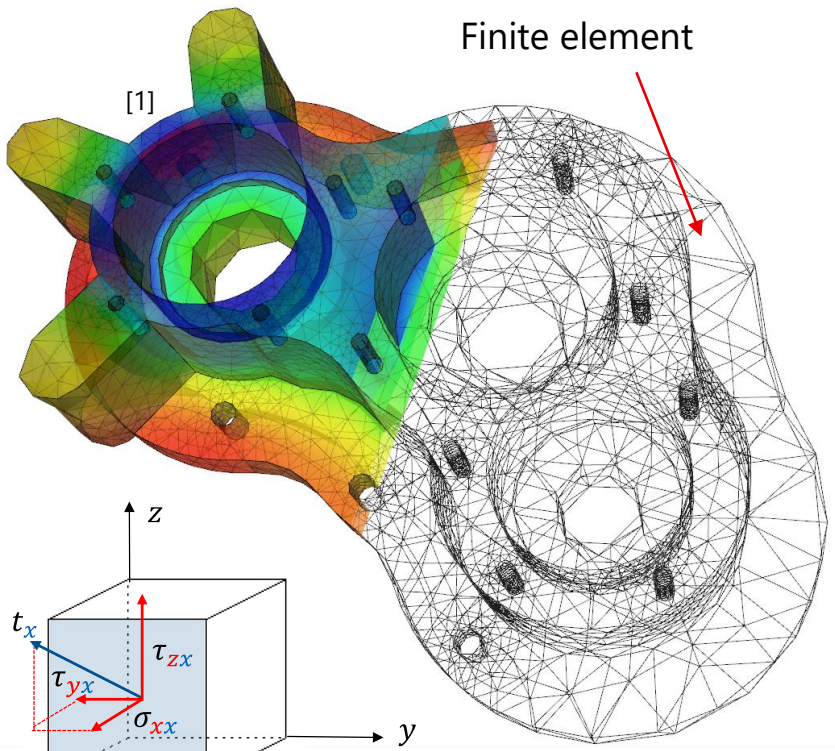
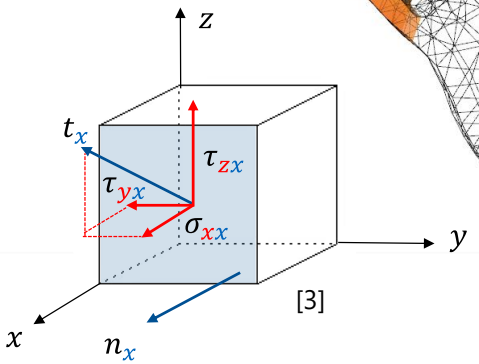
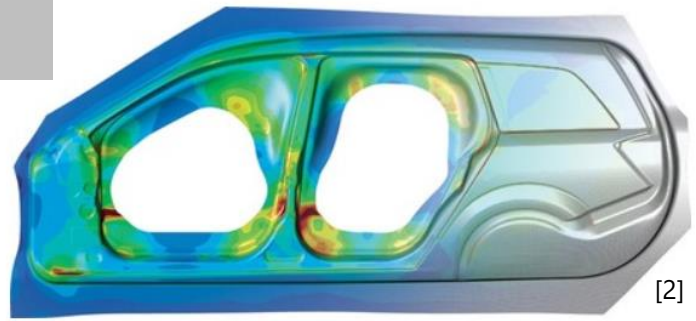
Finite element simulation is a numerical description of material and component behavior.





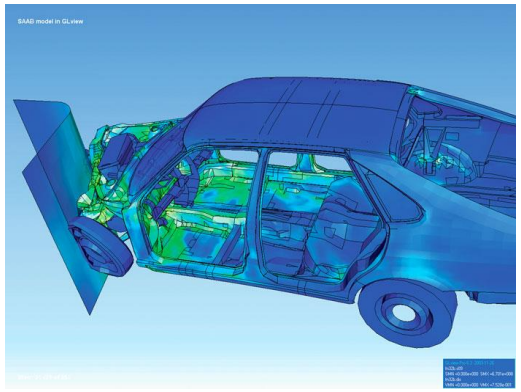
Quasi-static material card

Forming simulation


[2]

Many different types of simulation applications

Crash simulation


[1]

Dynamic material card

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FE simulation tries to reproduce the real process as well as possible on the basis of material data.

Real system

Material characterization and modelling

Calibration

FE Simulation

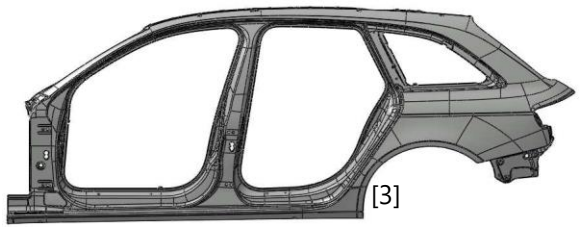
Validation

Geometry

Material

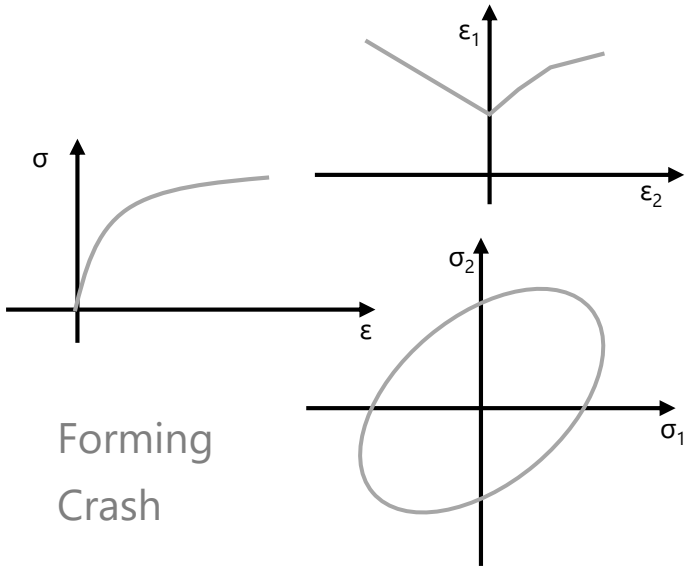
Strain rate

...



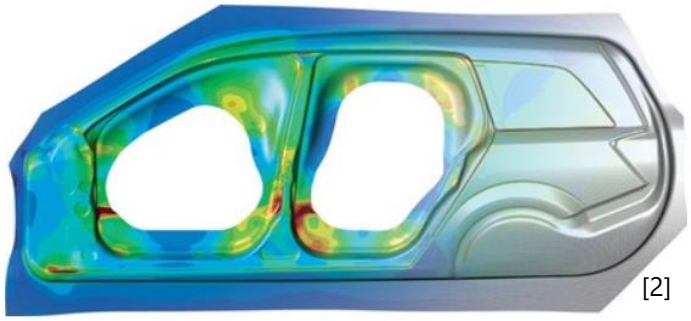
[3]

Process



Forming

Crash



[2]

Requirements from the real system → Characterization of the materials under conditions as close to reality as possible → Precise prediction of the forming behavior

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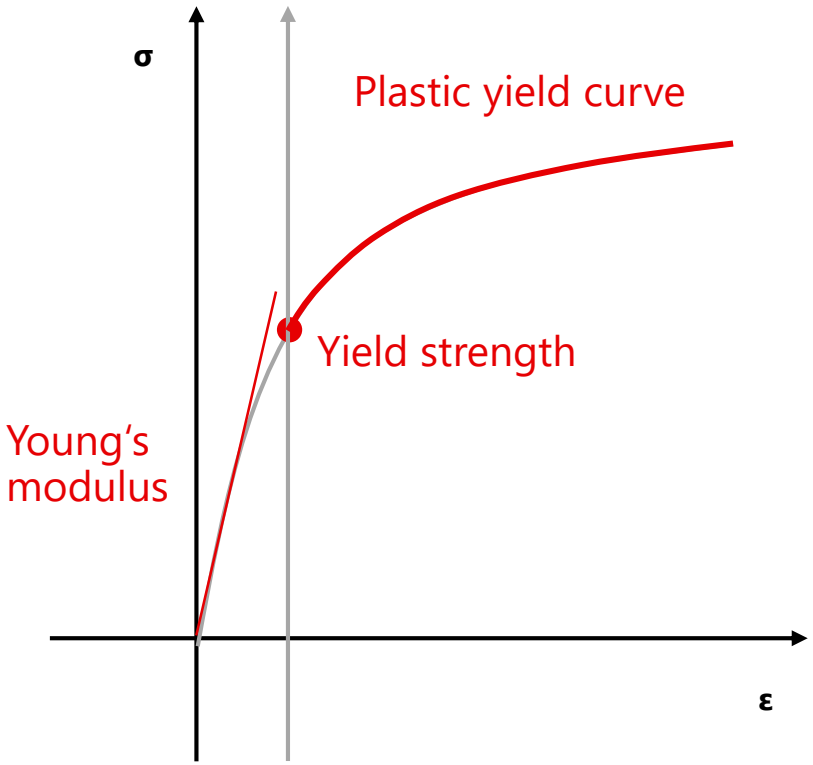
Material characterization creates the basis for material modeling.



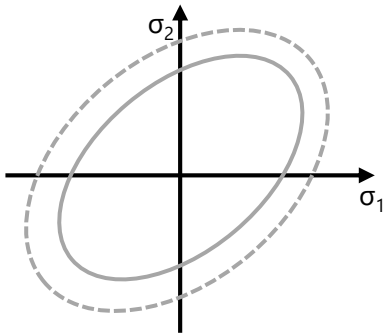
Material characterization

Provides reference data values for the material behavior

- **Yield strength 0.2%**
- **Tensile strength**
- **Young's modulus**
- **....**

Material modelling

Uses the experimentally determined reference values in a mathematical material law to describe the material behavior also for further stress states



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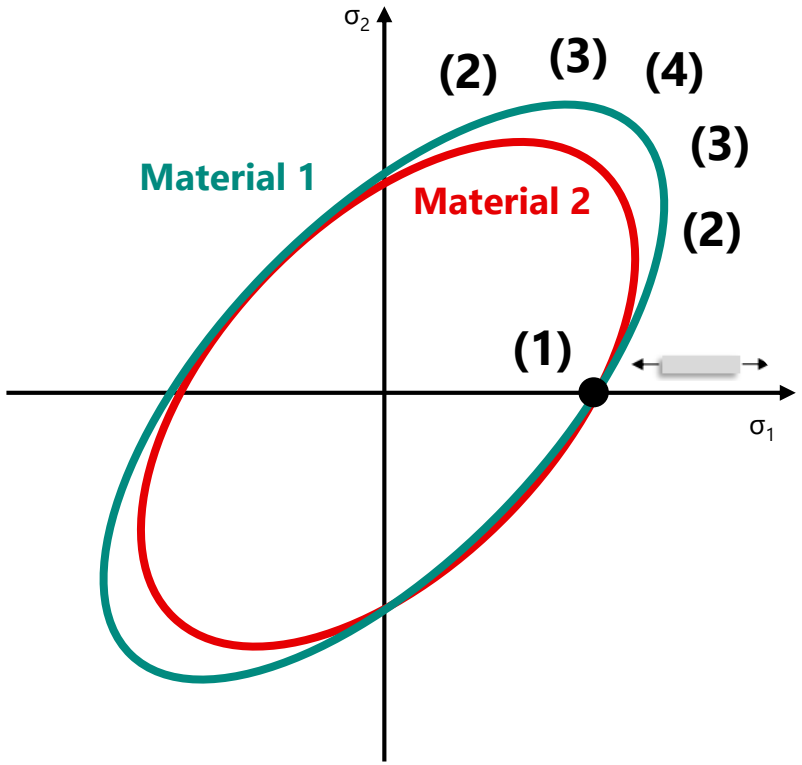
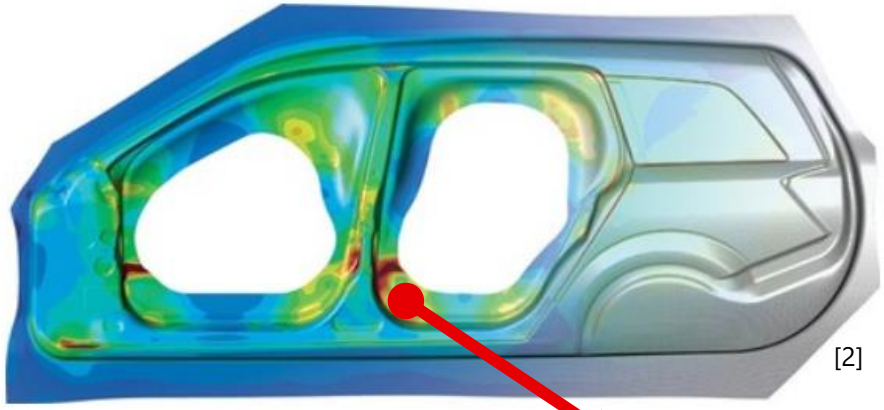
In reality, complex stress and strain states occur that must be represented by the material model.





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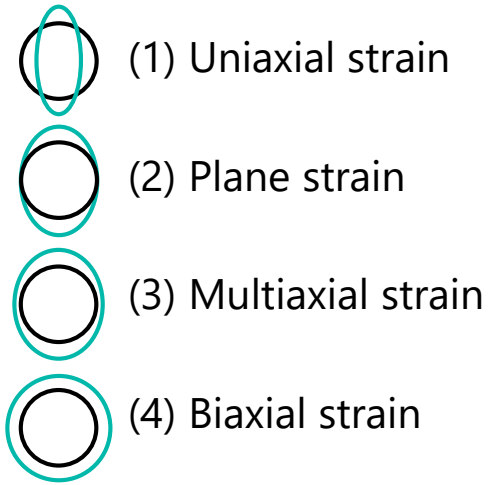

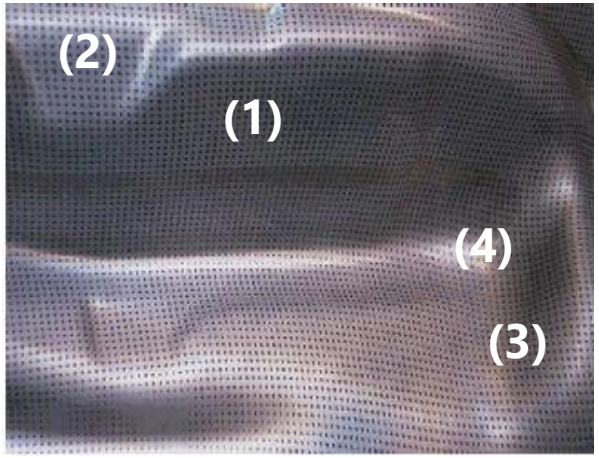

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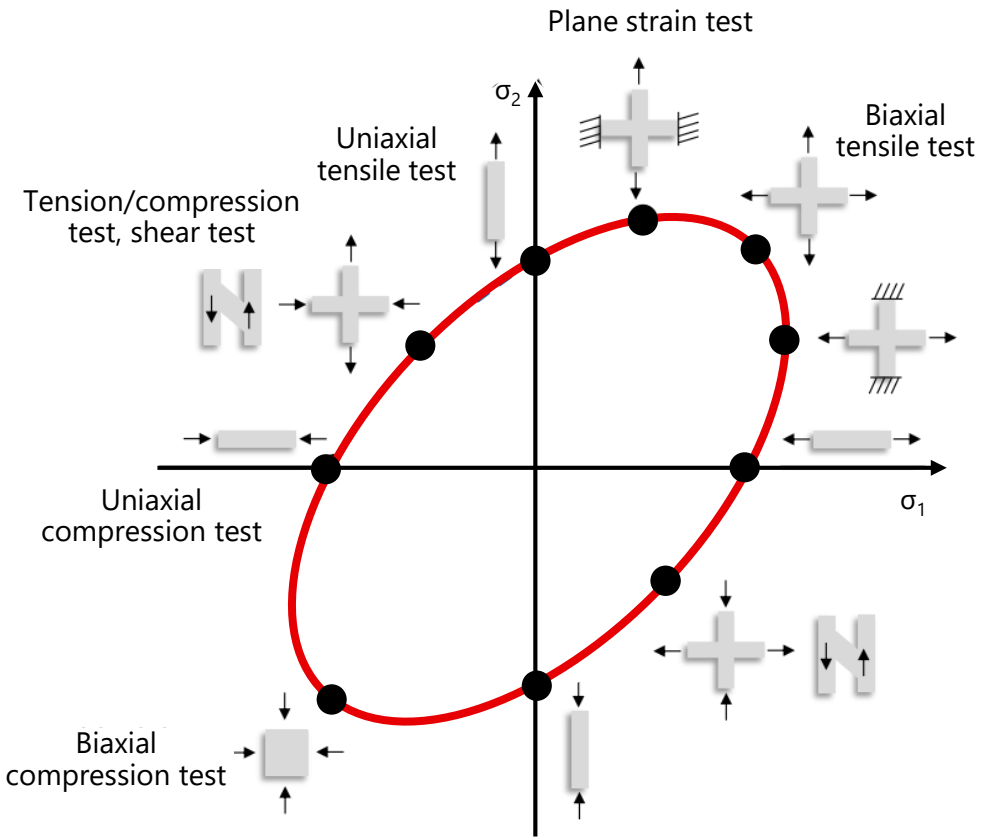
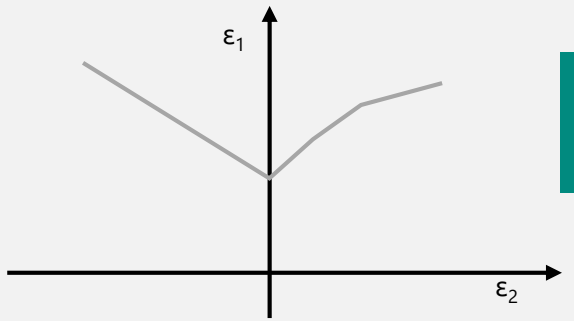


More complex material characterization as well as material modeling is necessary

As accuracy increases, so does the demand for mechanical testing

Forming limit diagram



Analogous to failure modeling

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The experimental effort has strongly increased.

1998

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2019

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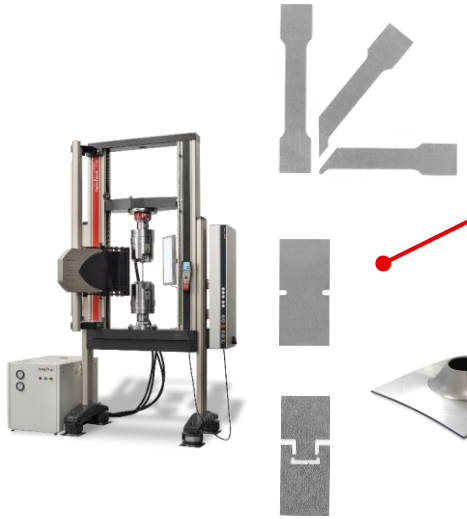

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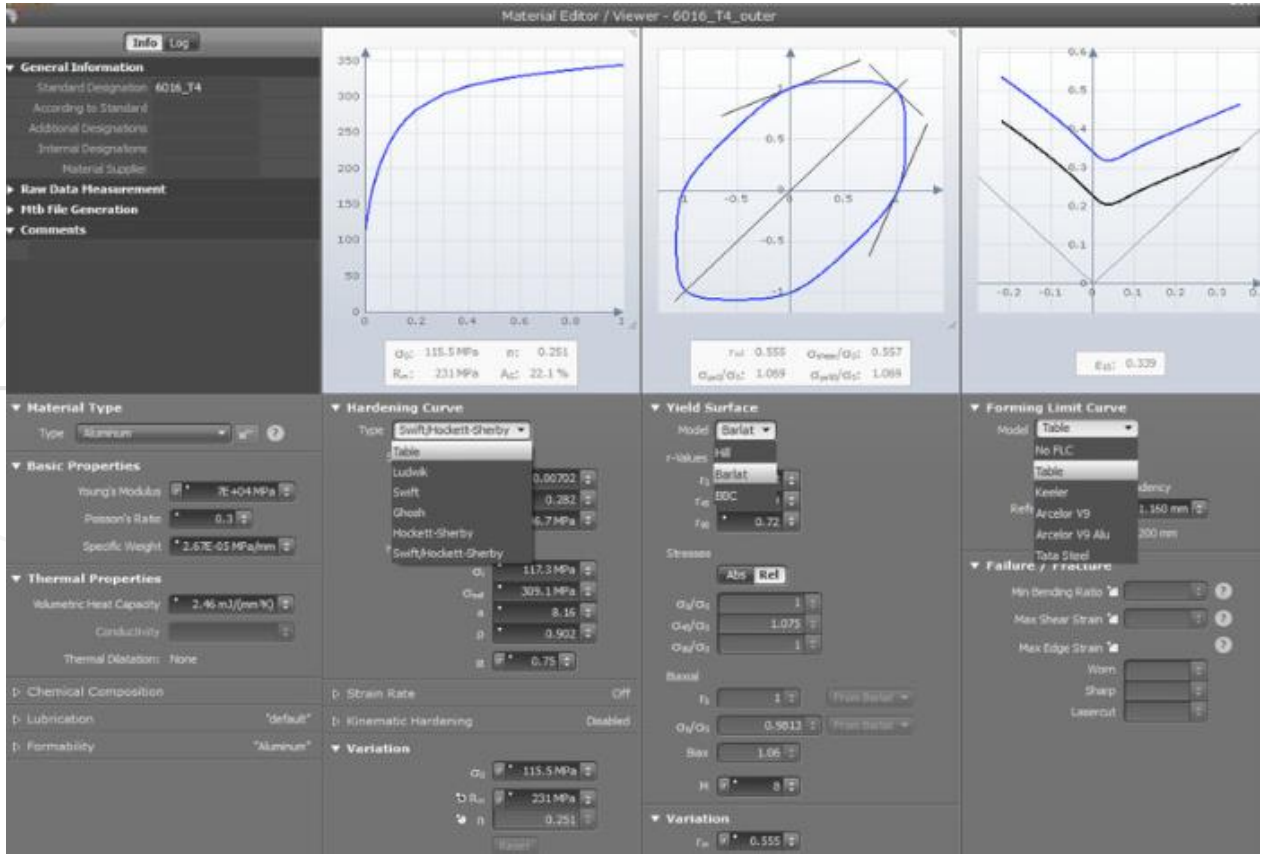
Basically, a yield curve, a yield locus and a forming limit diagram are stored for a simulation model.

Yield curve

AUTOFORM Forming Reality [7]



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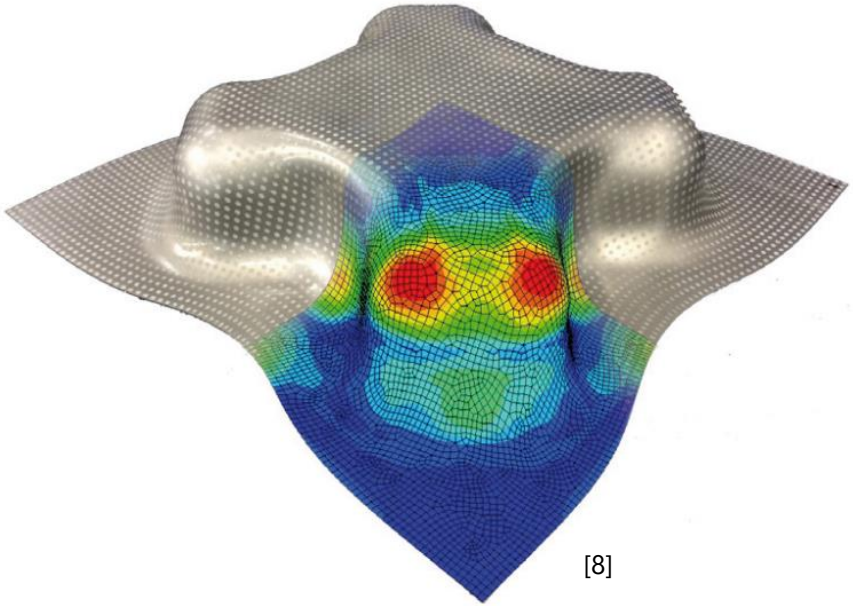
For validation, a modified experiment is re-simulated and the results are compared.

Industrial approach

e.g. Cross cup validation



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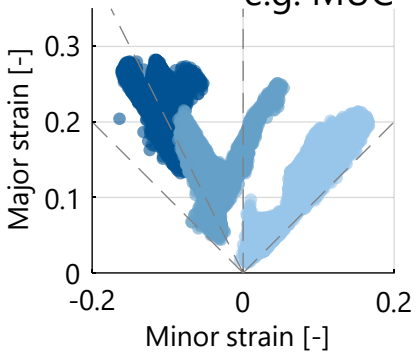
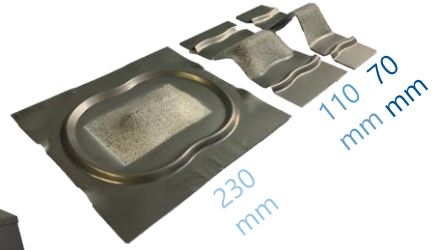
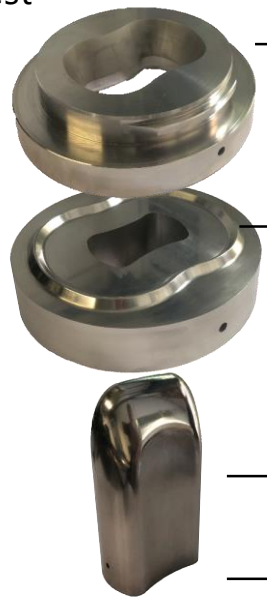
Academic approach

e.g. MUC – Test







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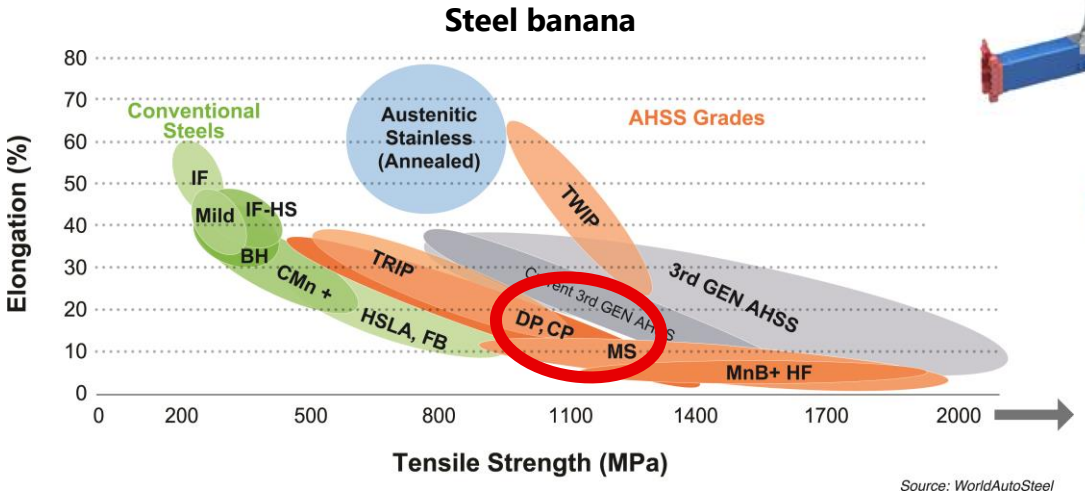
Modern car bodies consist of a wide variety of materials and complex joints.

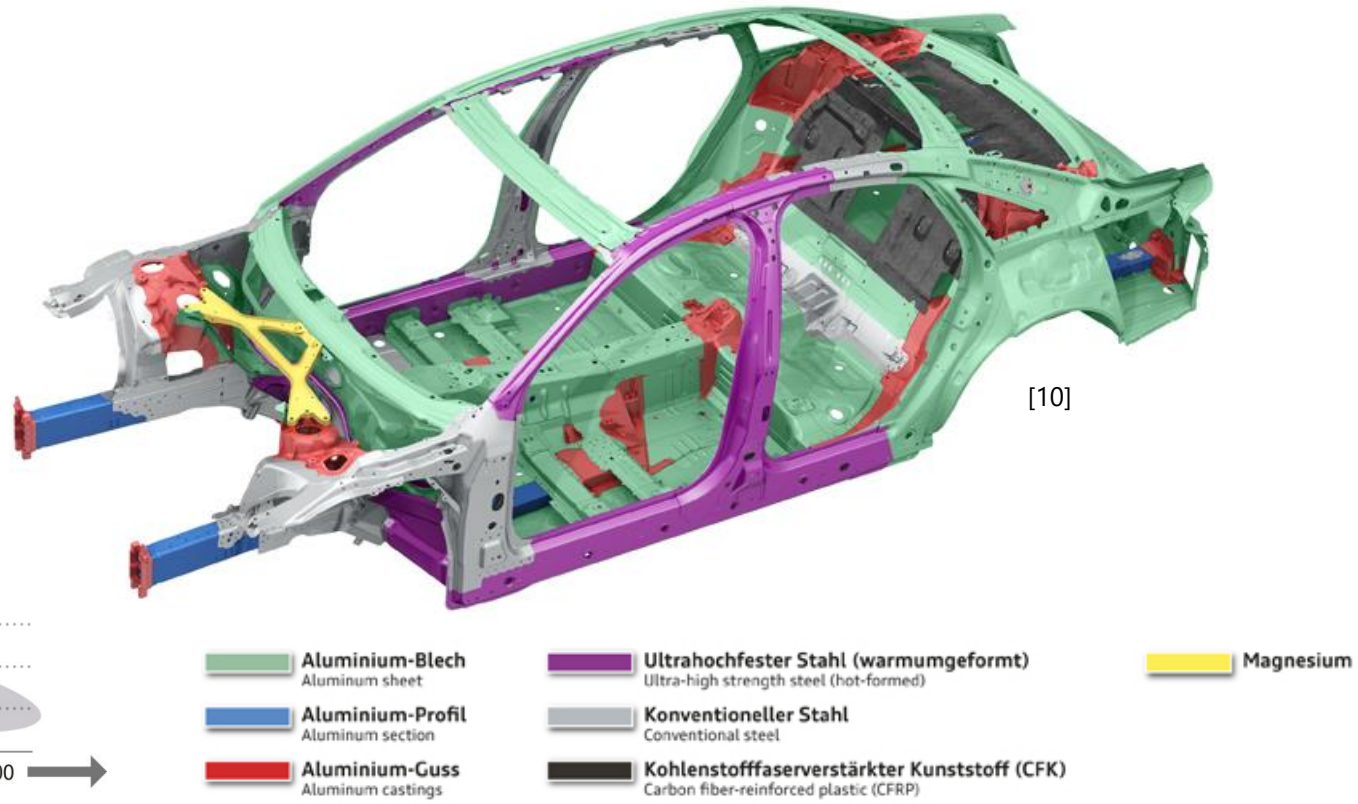
Challenge of the material mix

- Forming and crash simulation for a wide range of materials
- Simulation of composite materials
- Simulation of joints



Source: WorldAutoSteel

[13]



[10]

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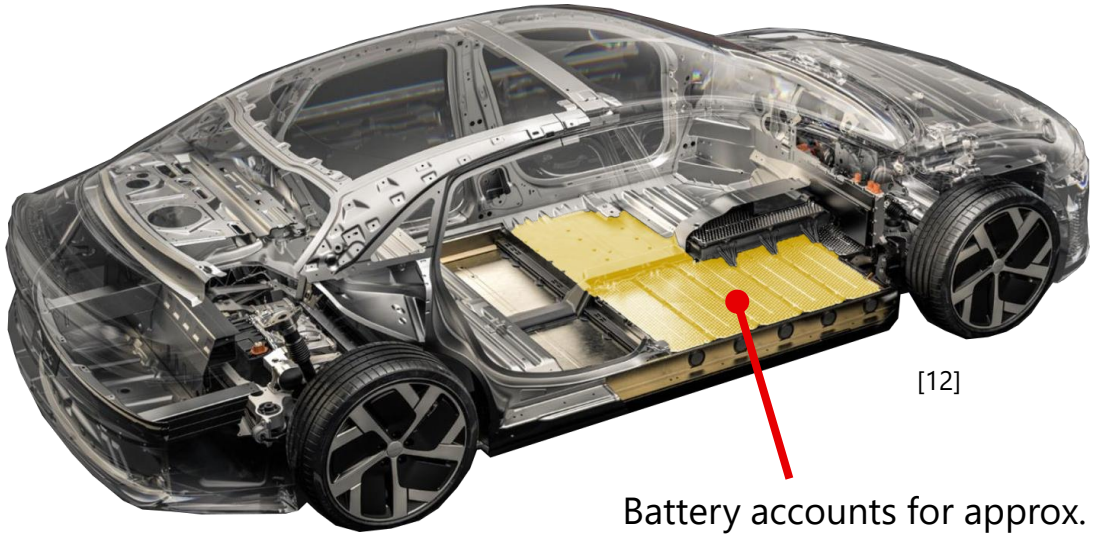
Lightweight constructions directly influence the range of electric vehicles (EV) and thus also the costs.



[12]

Battery accounts for approx.
30 % of the total cost of an EV

Example

1500 kg EV

20 % weight reduction ~ 1100 Euro [11]

18 % lower battery capacity ~ 3200 Euro

Material

Strength ⟷ Weight

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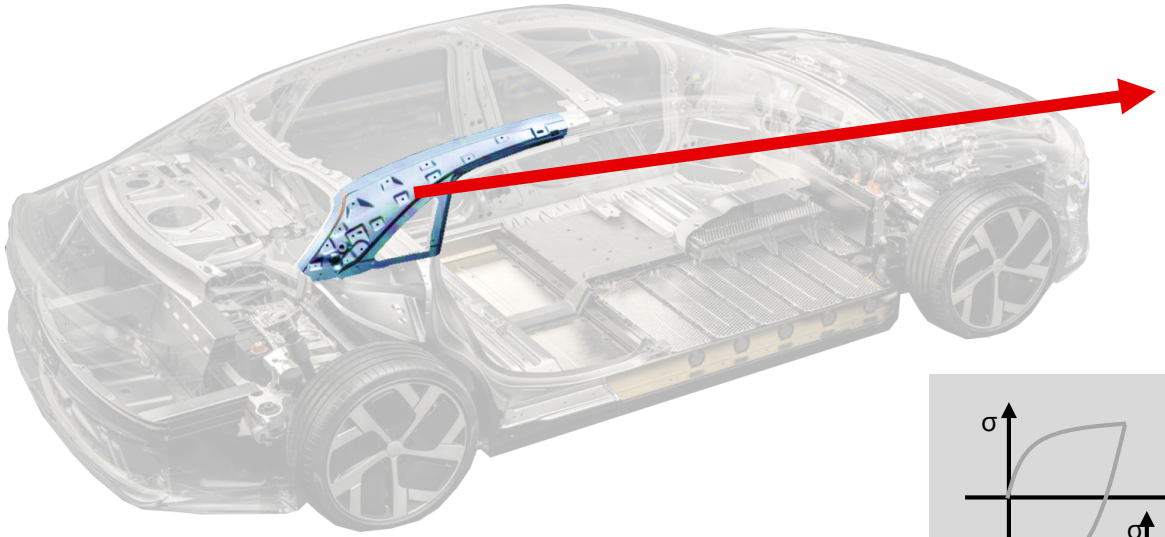
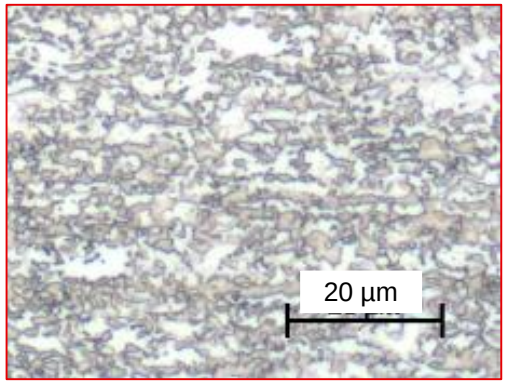
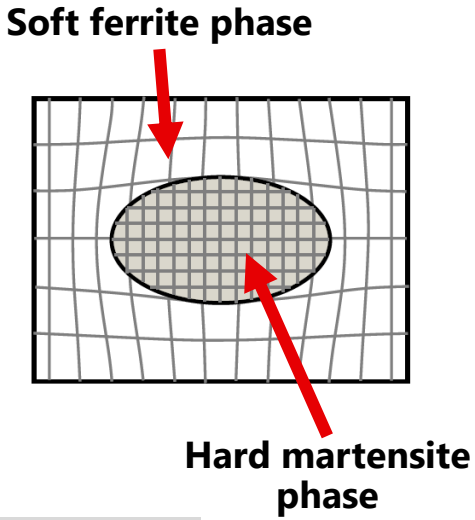
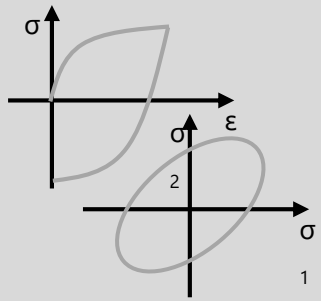
Special multiphase steels are used to implement lightweight construction.



Dual phase steel







Complex material behavior

- Variable Young's modulus
- Kinematic hardening
- High edge fracture sensitivity

[14]

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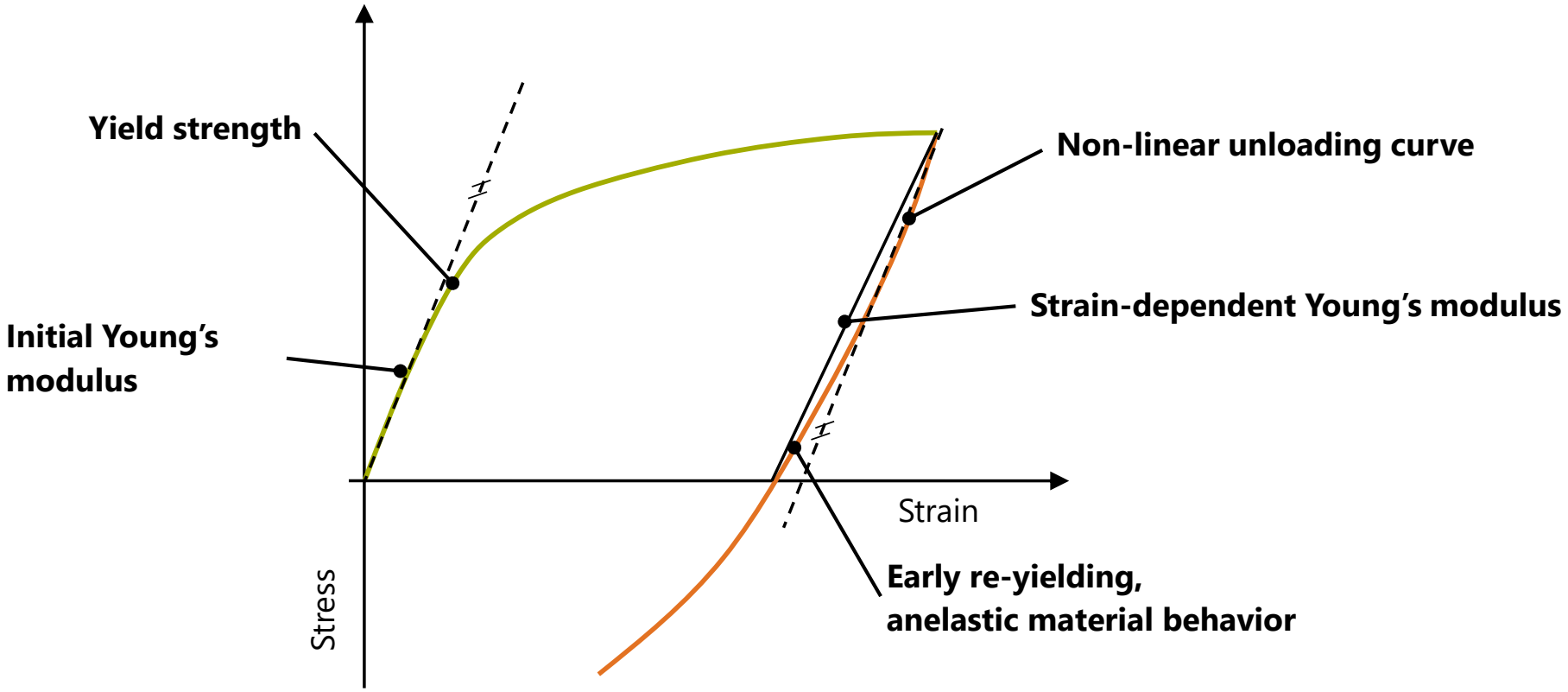
Dual-phase steels can deviate from general material theory in elastic-plastic behavior.



[14]

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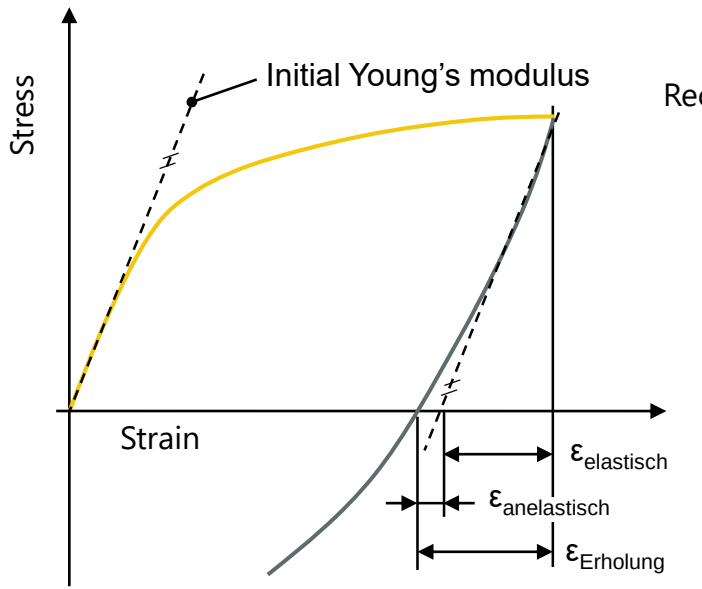
Variable elastic modulus leads to incorrect prediction of springback.



$$\varepsilon_{rec} = \varepsilon_{el} + \varepsilon_{an}$$

Recovery strain = Linear elastic strain + Anelastic strain

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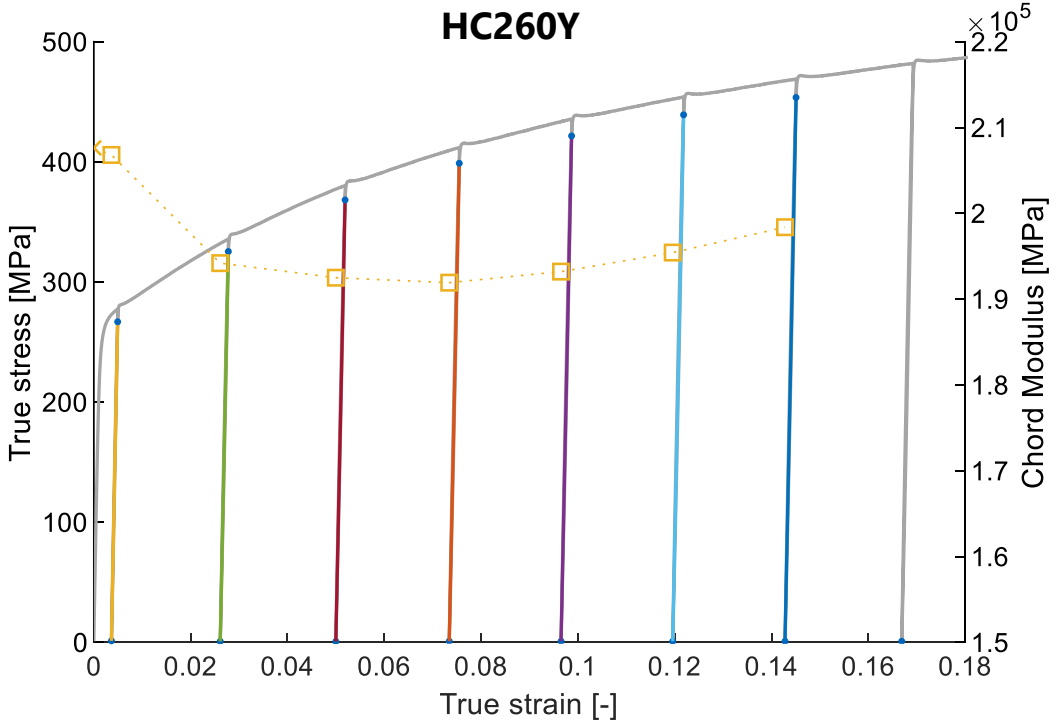
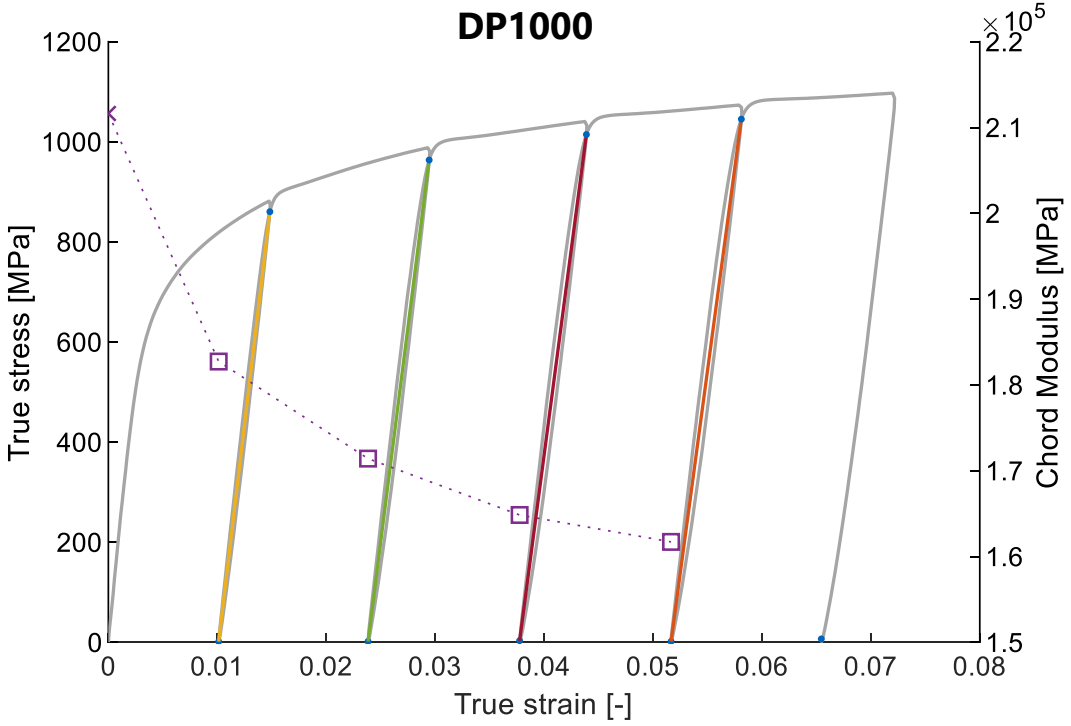
Increasing plastic deformation can result in a decrease in elastic modulus of up to 25%.





[14]

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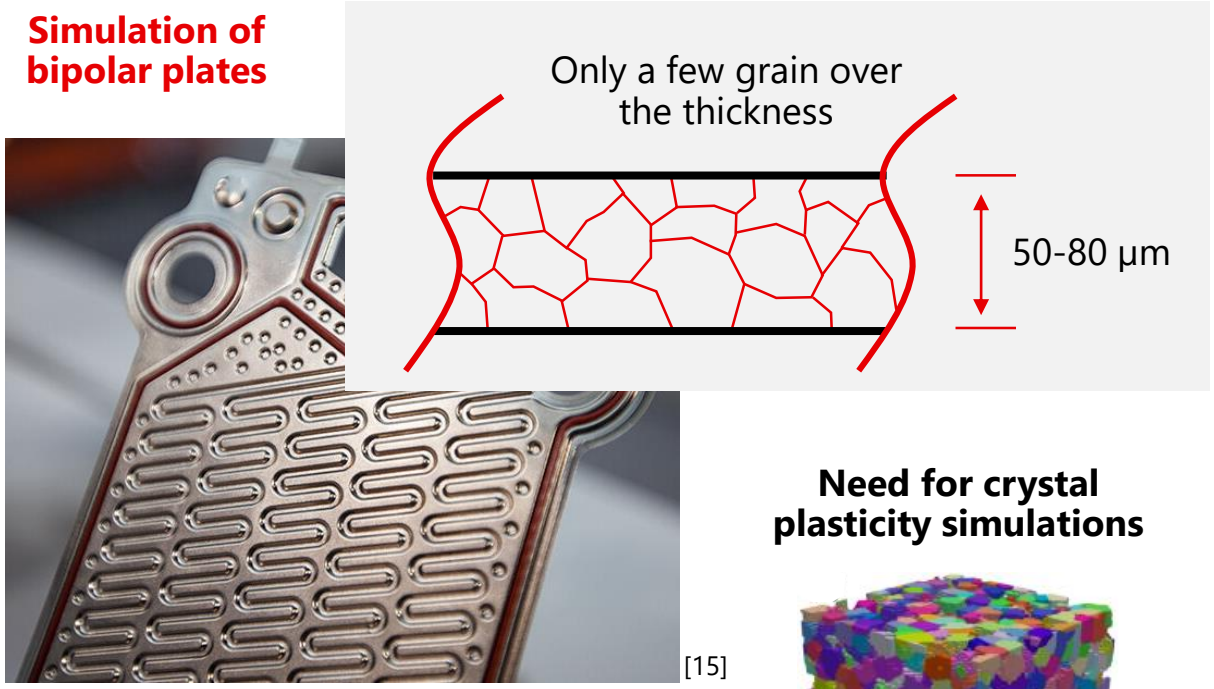
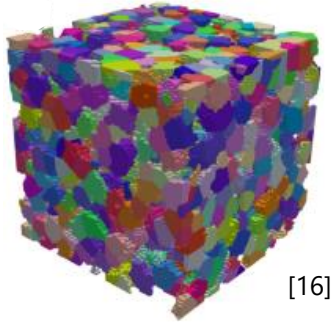
New challenges posed by technologies in e-mobility.

Simulation of bipolar plates



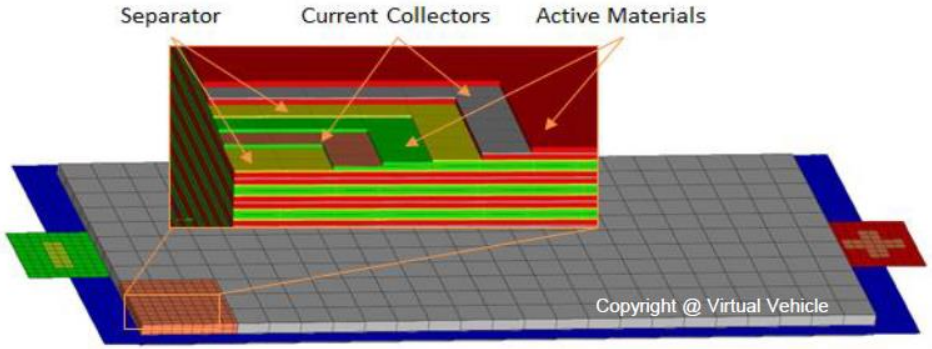
[15]

Need for crystal plasticity simulations



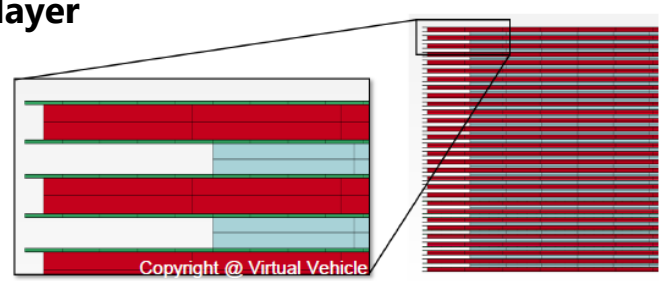
[16]

Battery cell simulation at component level



Characteristic values are assigned to each layer

[17]



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The requirements for mechanical testing will continue to increase.

2019

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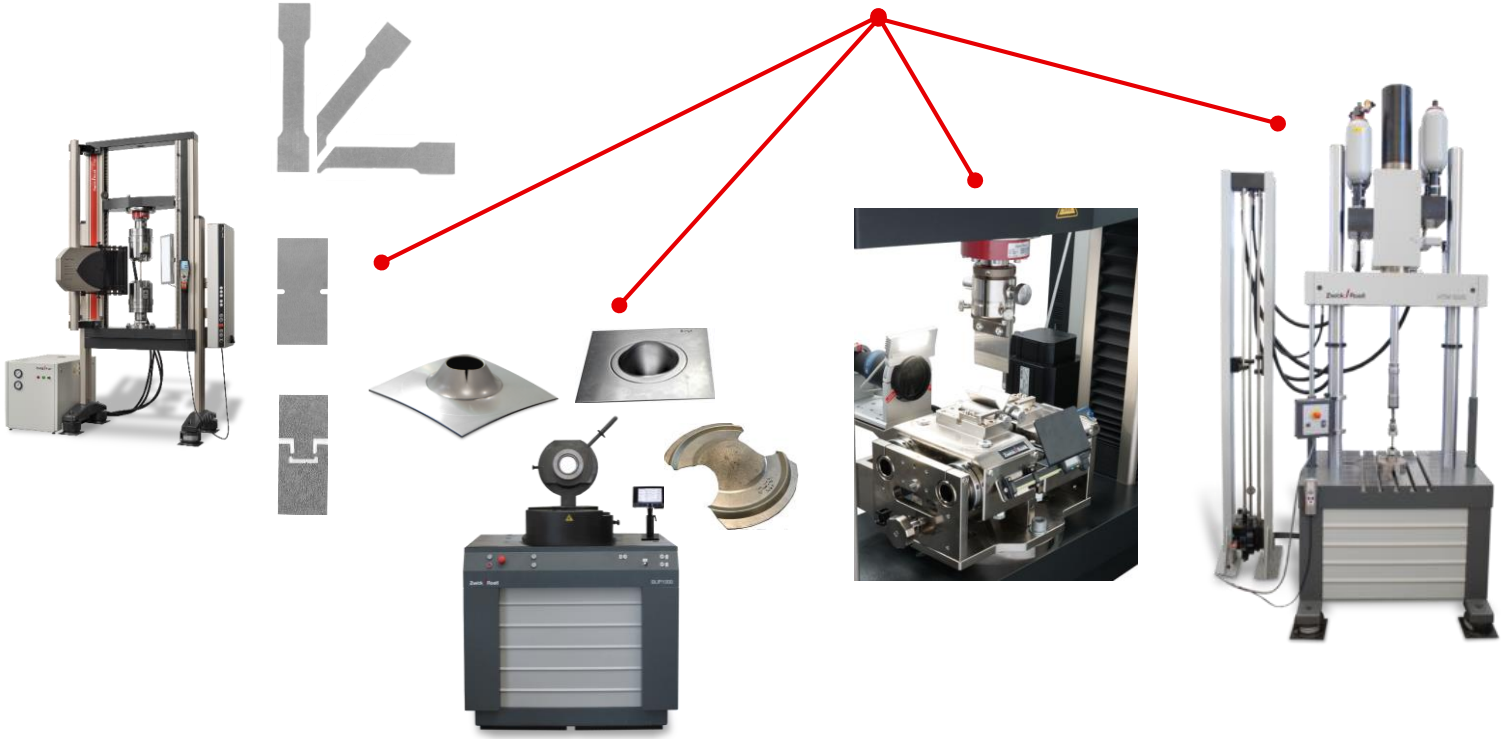
20XX

[18]



- **Increased computing power allows even more complex material models**
- **New and multifunctional materials for e-mobility place high demands on simulation**

Source: autoscout24.de, bmw.de, ecomento.de

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Referenzen

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